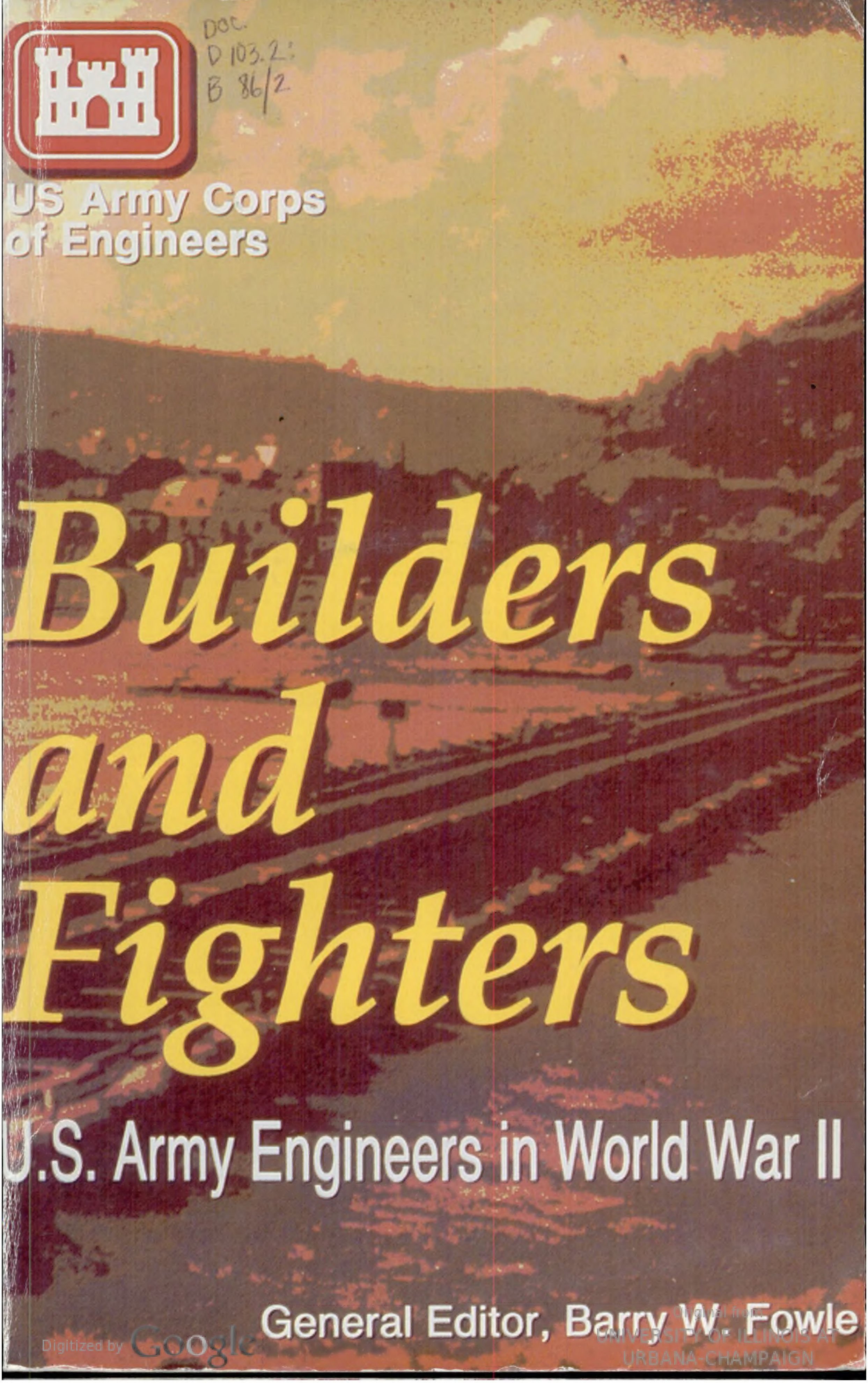

US Army Corps
of Engineers

Builders and Fighters

U.S. Army Engineers in World War II

General Editor, Barry W. Fowle

The cover is based on a photograph of a treadway bridge across the Rhine at Honningen, Germany.

The photographer, Colonel H.F. Cameron, Jr., USA (ret), commanded the 164th Engineer Combat Battalion at the time the bridge was constructed. Colonel Cameron's combat battalion was responsible for installing protective booms for the bridge.

Lieutenant Colonel Loren A. Jenkins' 254th Engineer Construction Battalion—assisted by the 994th and 998th Engineer Treadway Bridge Companies—built the 1,368-foot M-2 steel treadway bridge in 12 hours on 22 March 1945.

Named the Victor Bridge, it was the longest bridge built over the Rhine in the First Army area.

BUILDERS AND FIGHTERS:
U.S. ARMY ENGINEERS IN WORLD WAR II

Barry W. Fowle

General Editor

OFFICE OF HISTORY
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Foreword

The Corps of Engineers played an important part in winning World War II.

Its work included building and repairing roads, bridges, and airfields; laying and clearing minefields; establishing and destroying obstacles; constructing training camps and other support facilities; building the Pentagon; and providing facilities for the development of the atomic bomb.

In addition to their construction work, engineers engaged in combat with the enemy in the Battle of the Bulge, on the Ledo Road in Burma, in the mountains of Italy, and at numerous other locations.

Certainly one of the highlights of Corps activity during World War II was the construction of the 1,685-mile Alaska Highway, carved out of the Canadian and Alaskan wilderness.

Builders and Fighters is a series of essays on some of the hectic engineer activity during World War II. Veterans of that war should read this book and point with pride to their accomplishments. In it, today's engineers will find further reasons to be proud of their heritage.

H. J. HATCH
Lieutenant General, USA
Chief of Engineers

DEPARTMENT OF DEFENSE
50th
ANNIVERSARY
OF
WORLD WAR II
1941-1945 • COMMEMORATION • 1991-1995

To the soldiers and civilians
of the Corps of Engineers
for their accomplishments during World War II.

Acknowledgements

In June 1945 the U.S. Army had almost 600,000 engineer troops organized into more than 2,000 separate units. All of these builders and fighters—and the thousands of Corps civilians and hundreds of contractors who supported them—are responsible for the engineer contribution to the Allied victory in World War II.

No single historical volume could do justice to all the engineer achievements. This collection of essays contains only a sampling of the many activities that occupied the Army engineers. By recognizing the accomplishments of some, the authors acknowledge the accomplishments of all those engineers who served their country so well.

Contributors to this book include the members of the Office of History, U.S. Army Corps of Engineers; several former members now with the Center of Military History; and a number of Corps field historians located at the various divisions and districts throughout the country. Short biographies of the authors are located near the back of this book.

The staff of the Office of History has contributed invaluable assistance throughout. Frank N. Schubert initiated the project and assigned it to me. William Baldwin and Charles Hendricks assisted by reading and commenting on the various articles. James W. Dunn was especially helpful in reviewing several articles.

Others contributed to this book. Patricia K. Paquette, Visual Information Center, performed extraordinary work by preparing the maps and providing artwork for the cover. Jim Dayton copied and enhanced all photographs. Helena Joy Brown proofread the first draft, and Susan Carroll carefully prepared the index. Marilyn G. Hunter, Office of History, advised on editorial matters and guided the manuscript through its final stages of production.

To all who assisted in the preparation of the book, I am grateful.

Barry W. Fowle

Barry W. Fowle
General Editor

Introduction

In terms of both its immediate and long-term impacts on the lives of Americans and on the nation's role in the world, World War II stands out as one of the most significant events in our history. It was the most devastating war in American history, it brought about major transformations in culture and society, and it saw great technological advances resulting from military research. The end of the war actually marked the beginning of a long "Cold" War in which America and its democratic institutions obtained vastly enhanced influence in the evolution of international affairs—ultimately leading to the collapse of communism.

World War II also formed a significant chapter in the long and proud history of the U.S. Army Corps of Engineers. In the fall of 1940, as Hitler's armies continued their march across Europe, the Corps was engaged in a growing mobilization effort to counter the German threat. A year later, the Japanese bombed Pearl Harbor, and the United States was at war.

The conflict that followed tested the engineers' mettle from North Africa and Europe to New Guinea and Burma. Outside the United States, engineers built roads, bridges, airfields, and pipelines; cleared mines; dredged harbors and repaired ports; completed the Alaska Highway and Ledo Road; and often fought as infantry.

At home, the Corps conducted the planning, land acquisition, design, contracting, and construction associated with a $15.3 billion mobilization program that included training camps, depots, hospitals, and ammunition plants. The Corps' Manhattan District constructed facilities to support development, testing, and deployment of the atomic bomb. After the Corps took over responsibility for military construction from the Quartermaster Corps in December 1941, the ongoing Pentagon construction project was one of the Corps of Engineers' largest endeavors.

To commemorate these accomplishments, the Office of History has prepared this book of essays. This volume is not

comprehensive, but rather seeks to present a representative sampling of the engineers' activities in the war. Hence, many individuals, units, and actions are not included; but their contributions to the greatest Army engineer effort in American history were no less significant.

We hope that the story which is told in these pages will educate and inspire all who read it, as well as recognize and honor the deeds of the men and women of the Corps who served as builders and fighters in World War II.

Paul K. Walker

Paul K. Walker
Chief, Office of History
Headquarters, U.S. Army
Corps of Engineers

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BUILDERS AND FIGHTERS:

U.S. ARMY ENGINEERS IN WORLD WAR II

SECTION I

Mobilization

Before World War II, war planners in the United States believed that mobilization would begin when war started. They realized though that modern war required industrial mobilization at least two years before manpower mobilization. The Army's Industrial War Plan of the early 1930s established the basic principles for harnessing the nation's economic strength before a war, while the Protective Mobilization Plan of 1937 was based on a start of war, M-day, to begin building the initial manpower force. Both plans assumed a sudden start to any future war. In reality, mobilization occurred in a piecemeal fashion as the United States gradually approached World War II.

In the fall of 1938, shortly after the Munich crisis, President Franklin D. Roosevelt, at a meeting of his military advisers, called for an increase in military aircraft production. Army planners wanted to increase the ground forces as well, but the President was looking to the airplane for American defense.

Reexamining its plans, the Army saw no support for anything but a strategy of hemispheric defense. The neutrality acts of the late 1930s determined that the United States would remain isolationist, not enter foreign wars, and protect its national interests with a western hemisphere security force.

The September 1939 beginning of World War II in Europe had little impact on the Army. The President did proclaim a limited national emergency and authorize slight increases in the size of the Army and National Guard, but he felt the public would not support a large mobilization. He believed the Allies would eventually stop Hitler with force, if not diplomacy.

The dramatic German victories in western Europe in the summer of 1940, especially the defeat of France, had a

significant impact on the Army, including the Corps of Engineers. In June, a munitions program for the Army called for procurement by October 1941 of equipment for a force of 1.2 million. To fill the ranks of this enlarged Army, in August Congress approved the induction of the National Guard into federal service and the call up of the Army Reserves. The next month Congress passed the Selective Service Act, the first peacetime draft in the nation's history.

As the Corps increased in size and mission, there was a need for reorganization, as described in the first essay. A significant new mission, the fall 1940 air base construction program, is covered in the next three essays. The Corps' increased training mission is described in the final two essays.

Initially the Army had problems with the major increase in manpower. The regular force was too small to train and absorb the new arrivals, and equipment was in short supply. But Pearl Harbor ended the prewar phase, and suddenly the United States faced a global war. The Army was still training new arrivals and there were still significant equipment shortages, but wartime mobilization had begun.

The following essays provide some details of how the Corps of Engineers carried out its missions as the Army passed from the prewar phase to wartime mobilization.

Organization and Responsibilities

by Martin Reuss

In World War II, the Corps of Engineers was a sprawling organization with operations akin to a major international corporation. Its responsibilities reached from the production line in the United States to overseas battlefields. In 1941, when the Corps obtained broad military construction functions, it also had responsibilities to train engineer troops; procure, maintain, repair, and distribute engineer equipment for use in the theaters of war; produce maps; collect intelligence; build military highways and railroads; and cooperate with a variety of civilian organizations on efforts relating to industrial mobilization.

The War Department building in Washington, DC during World War II. Headquarters of the Corps of Engineers moved there in 1941. In 1947 the State Department took over the building and later substantially enlarged it.

Besides all these activities, the Corps retained its civil works responsibilities to develop and maintain navigable waterways, help control floods, and provide hydropower. The Corps of Engineers combined the functions of a school, research laboratory, department store, shipper, engineering

firm, repair shop, and construction organization. The challenges were enormous, but no organization, civilian or military, was better equipped to handle them.

While the wartime Corps, in keeping its traditional methods of operation, often delegated authority to the organizational element with direct responsibility for execution, the Headquarters of the Corps of Engineers retained overall oversight and coordination functions.

The Chief of Engineers personally retained broad responsibilities and a large span of control. For instance, although actual engineer training was the responsibility of three replacement training centers and three unit training centers under the jurisdiction of the service commands, the Chief of Engineers continued to oversee the evolution of engineer training doctrine and publications; and he supervised the development of engineer equipment for the Army ground and air forces and some items of engineer equipment used by the Navy and the Allied forces (under the lend–lease program).

After December 1941 the Chief of Engineers oversaw the acquisition and disposal of military real estate, carrying out the responsibilities assigned him by the Under Secretary of War, and the construction and maintenance of buildings and other facilities for the Army. He supervised the Army Map Service, established as an Army engineer field office in 1942 to develop topographic maps of actual or potential combat areas. Under the direction of the Secretary of War, he continued to discharge his civil works responsibilities. Finally, he advised the Chief of Staff on all Army engineer matters.

Major General Julian Schley, Chief of Engineers from October 1937 to October 1941.

The wartime Chiefs of Engineers were Major General Julian L. Schley, who held the post from October 1937 to October 1941, and Major General Eugene Reybold, the incumbent

from October 1941 to October 1945. In 1939–40 an Assistant Chief of Engineers served as head of the civil works section, while another Assistant Chief headed the military section. Both were general officers. From 1941 to 1943 four Assistant Chiefs of Engineers supervised the Administration, Construction, Supply, and Troops divisions. During this period, each Assistant Chief was a brigadier general except for the Construction Division head who was a major general. From early 1943 to April 1945, a Deputy Chief of Engineers, several special assistants, and two Assistant Chiefs of Engineers, one for military supply and one for war planning, reported directly to the Chief of Engineers.

Lieutenant General Eugene Reybold, Chief of Engineers from October 1941 to October 1945. Reybold was promoted to Lieutenant General on 15 April 1945, the first to hold that rank while serving as Chief of Engineers.

Office of the Chief of Engineers		
Assistant Chief of Engineers	**Assistant Chief of Engineers**	**Boards and Commissions**

Personnel Division
Intelligence Division
Operations and Training Division
Supply Division
Construction Division
  Plans and Development
  Budget Design and Operations
Railway Division
	Rivers and Harbors Division
	  Navigation Projects
	  Flood Control Projects
	Miscellaneous Civil Division
	Finance and Accounting Division
		Mississippi River Commission
		Beach Erosion and Shore Protection Boards
		Board of Engineers for Rivers and Harbors
		  Engineering
		  Administration
		  Review of Reports
		  Statistics
		  Special Studies
		  Cost Accounting
		  Safety

1 August 1940 Reorganization, Office of the Chief of Engineers.

As chief of a technical service, the Chief of Engineers reported to the Commanding General of the Army Service Forces (ASF), Lieutenant General Brehon B. Somervell (also an engineer officer), on questions relating to military supply activities. However, the Corps of Engineers, like other technical services such as the Ordnance, Transportation, and Signal

Corps, successfully resisted efforts by General Somervell to divest it of field functions and make the Office of the Chief of Engineers purely a functional staff component within the ASF.

On 27 February 1941, a few months after the transfer of airfield construction, the Office of the Chief of Engineers was reorganized into nine sections: personnel, intelligence, supply, operations and training, railways, fortifications, general office administration, construction, and miscellaneous civil engineering. Then, on 10 November 1941, the Chief of Engineers consolidated organizational elements of his office in anticipation of receiving broadened responsibility for general Army construction and related functions. He replaced the nine sections with four divisions—Construction, Supply, Troops, and Administration—two independent sections, and various boards and commissions.

Office of the Chief of Engineers		
Assistant Chief of Engineers Construction Division	**Assistant Chief of Engineers Supply Division**	**Assistant Chief of Engineers Troops Division**
Labor Relations Branch Engineering Branch Real Estate Branch Repairs and Utilities Branch Operations Branch Utilities Contracts Branch	Supply Control Section Administration Branch Requirements, Storage and Issue Branch Procurement Branch Development Branch Construction Materials Branch	Intelligence Branch Operations and Training Branch Railways Branch
Assistant Chief of Engineers Administration Division	**Boards and Commissions**	
Office Services Branch Civilian Personnel Branch Fiscal Branch Military Personnel Branch Contracts and Claims Branch Legal Branch	Board of Engineers for Rivers and Harbors Beach Erosion Board Shore Protection Board Mississippi River Commission Construction Contract Board Coast Artillery Advisory Committee	

6 June 1942 Reorganization, Office of the Chief of Engineers.

The Construction Division performed both civil and military activities. The Engineering and Operations branches, for example, did rivers and harbors work as well as military construction. The Supply Division addressed the development, procurement, storage, and distribution of military engineer equipment. The Troops Division encompassed training, operations, and intelligence functions. The Administration Division included the usual support operations, including personnel, financial, and legal responsibilities. The two

independent sections were Control (largely to insure proper coordination of staff actions) and Public Relations.

With one exception—the establishment of a separate Engineering Division in May 1943—the basic organizational structure of the Office of the Chief of Engineers remained generally unchanged until the end of 1943 although several small units were added. Occasionally, the Secretary of War or Headquarters, ASF, required new offices to be established. These included price adjustment and cost analysis sections, a technical information branch (which included public relations), strategic studies, reproduction control, and a manpower board.

The Engineering Division consolidated several functions that had formerly been divided between the Construction and Supply divisions. The new division prepared engineering studies; developed and prepared plans, specifications, and design criteria for facilities and equipment; and drafted the engineering sections of manuals and other publications.

The complete rearrangement of functions on 1 December 1943 demonstrated the flexibility of the Chief of Engineers to meet rapid changes in the combat situation. Attention shifted from activities in the United States to military operations overseas as the Army expedited the flow of men, materiel, and scientific and technical information. The centralization of engineering and development functions continued. This was partially accomplished with the establishment of the Engineering Division the previous May. The Chief integrated war planning and military intelligence more closely, and he established better coordination among military procurement, supply, and maintenance activities.

While the Chief consolidated some functions, he further decentralized others to maintain a reasonable span of control. Nine headquarters divisions replaced the five old ones. Previously, all division heads had reported directly to the Deputy Chief of Engineers. Henceforth, six of the division chiefs reported to two Assistant Chiefs of Engineers. The Procurement, Supply, and International divisions reported to the Deputy Chief of Engineers through the Assistant Chief of Engineers for Military Supply, while the Engineering and Development, Military Intelligence, and War Plans divisions reported to the Deputy Chief of Engineers through the

Assistant Chief of Engineers for War Planning. The remaining three divisions—Civil Works, Military Construction, and Real Estate—reported directly to the Deputy Chief of Engineers. This was also the chain of command for the independent branches that dealt with fiscal, legal, personnel, safety, and public relations matters.

Two new divisions appeared during the first half of 1944. The Maintenance Division was established on 1 January 1944. It was formerly the Maintenance Branch of the Supply Division but its increasing workload and personnel resulted in its upgrade to a division. Its chief reported to the Assistant Chief of Engineers for Military Supply. The second new division was Readjustment, established on 15 May 1944. This division consisted of the Price Adjustment, Demobilization Planning, Contract Termination, and Redistribution and Salvage branches, all of which had been previously activated for the economical termination and disposition of contracts and equipment at the close of the war. The Price Adjustment Section had been set up during fiscal year 1943 to renegotiate contracts that were expiring and had been made a branch by December 1943. The Demobilization Planning Branch was formed on 17 January 1944 to plan for adjusting construction, real estate, distribution, procurement, and lend–lease activities at the end of the war. The Chief of Engineers charged it with the direction, control, and supervision of demobilization planning for all agencies under his jurisdiction.

In further anticipation of the close of the war, the Contracts Termination Branch was created on 21 February 1944, to negotiate the termination of contracts whose completion was no longer required. The Office of the Chief of Engineers drafted new regulations and procedures to supervise these activities, which were mainly performed in field offices. Further changes removed the Redistribution and Salvage Branch from the Supply Division. It was made a separate branch on 20 March 1944 in order to meet the increasing workload in the disposal of surplus material. The merger of the four branches into the Readjustment Division facilitated the coordination and integration of long-range planning so demobilization, redeployment, and readjustments could be made in an economical and expeditious manner.

During the latter half of 1944, redeployment and readjustment problems became the focus of attention. Corps officials exhaustively studied headquarters and field offices in order to recommend changes to enable the Corps to respond effectively to these new concerns. Subsequently, on 30 April 1945, a new organizational structure placed the operating divisions under six directors: military supply, military operations, military construction, real estate, readjustment, and civil works. Division office structures in the field were generally made to parallel that of the Office of the Chief of Engineers.

Office of the Chief of Engineers		
Director of Military Supply	**Director of Military Operations**	**Director of Military Construction**
International Division Requirements and Stock Control Division Storage and Issue Division	Plans and Training Division Military Intelligence Division Requirements, Storage and Issue Branch Procurement Branch Development Branch Construction Materials Branch	Engineering Division Command Construction Division Industrial Construction Repairs and Utilities Division
Director of Real Estate	**Director of Readjustment**	**Director of Civil Works**
Acquisition Division Reality Requirements Division Management and Disposal Division	Demobilization Planning Division Price Adjustment Division Contract Termination Division Redistribution and Salvage Division	Administration Division Engineering Division Flood Control Division Rivers and Harbors Safety and Accident Prevention

30 April 1945 Reorganization, Office of the Chief of Engineers.

Only when we turn our focus from headquarters to actual operations in the field can we truly appreciate the enormous scope and complexity of Army engineer activities. The complexity was not simply a result of the many engineer responsibilities. It also reflected overlapping lines of authority. For example, division engineers in the field assumed direct control of the repairs and utilities activities at Army military bases, once these functions, along with military construction responsibilities, were transferred to the Corps in December 1941. However, after General Somervell transferred repair and utilities responsibilities to the service commands on 22 July 1942, the division engineers became staff officers to the service commanders. As a member of the service commander's staff, the division engineer was first given the title of Director of Real Estate, Repairs and Utilities, but later was called the Service Command Engineer.

This assignment of dual functions presented a problem to division engineers because the boundaries of the divisions and service commands were not identical. There were 11 divisions but 9 service commands. Furthermore, since the divisions were originally established for civil works, their boundaries followed drainage basins, while the service commands utilized state boundaries. In some cases, division and service command headquarters were not located in the same city. Accordingly, on 1 December 1942 all but two of the 11 divisions were made coterminous with those of the 9 service commands.

Because flood control and navigation remained the principal responsibilities along the Mississippi River, the Corps retained watershed boundaries for the Upper and Lower Mississippi Valley divisions. Headquarters offices were also moved so that, where possible, the division and service command offices were located in the same or adjacent buildings. Where this was not possible, they were at least in the same city.

Thus, by the end of 1942, 11 division engineers were engaged in Army construction. They decentralized the work to 60 district engineers who either performed the duties or further decentralized them to some 840 area engineers. Although districts were set up or abolished in accordance with work demands, this field organization remained generally unchanged throughout the war. At this time, the Corps employed 70,000 civilians in its field offices.

Civil works construction had long been carried out by 11 division and around 50 district engineers. When military construction became an engineer function, it too was performed by this same organization; but since some of the military construction was located in territories outside the United States, two additional divisions, and within them several districts, were created—the Northwest Division with headquarters at Edmonton, Canada, and the Pan American Division with headquarters at Miami, Florida. The Northwest Division handled engineer matters in Canada and Alaska, while the Pan American Division handled those in Central and South America and the Caribbean area.

The major types of military structures the Corps built were "command" facilities used in military operations such

as airfields, training areas, hospitals, storage depots and port facilities, together with related access roads, bridges, and utilities; "industrial" facilities, especially munitions plants and other factories under contract with the Technical Services; Manhattan District (atomic bomb project) structures; and the many civil works projects for which the engineers had long been responsible. Outside the continental United States, the Corps of Engineers built Army airfields, constructed air and naval bases in British possessions between Newfoundland and British Guiana, worked on the CANOL Project for building oil refineries and pipe lines in northwest Canada, and helped construct the Alaska (ALCAN) Highway through northwest Canada and the Pan–American Highway in Central America.

Insofar as possible, supply activities were also decentralized to the field. At the beginning of the war, responsibility for the procurement of engineer items of military supply was assigned to six procurement districts, headed by Army engineers who also served as heads of traditional Corps districts. These procurement chiefs reported directly to the Supply Division in the Office of the Chief of Engineers. In the ensuing war years, the responsibility was further divided so that at the height of procurement activity 55 field offices were involved, including all 11 continental United States engineer divisions. The Office of the Chief of Engineers made procurement allocations to the division engineers who selected the contractors and made letter purchase orders. A final adjustment in the field procurement organization was made one month later when the division engineers assumed jurisdiction over specific depots similar to their jurisdiction over engineer districts.

Sixteen engineer depots controlled the storage and issue of engineer supply items. At first, the Office of the Chief of Engineers set the stock level for each depot, but during fiscal year 1944 each depot determined its own stock level based on past issue experience and additional information furnished by the Supply Division, Office of the Chief of Engineers. In performing their mission, the depots initiated requisitions to maintain and replenish their stocks through regional control offices established for that purpose. The Office of the Chief of Engineers reviewed stock levels and, when gross requirements made it necessary, adjusted them.

The Corps' procurement system got the job done, although success in timely procurement and distribution varied from item to item. Despite the overall impressive record, critics within the Army, including some within the Corps of Engineers itself, thought the system grossly inefficient. Some accused the Corps of using the procurement function to hide its civil works personnel assets until after the war was over. In other words, in order to protect the civil works organization, which had a declining number of projects during the war, the Chief of Engineers involved civil works personnel in procurement operations and increased the number of procurement offices. Then, to protect its expanding procurement activity, the Corps enlisted the aid of congressional friends of rivers and harbors improvements. It is true that both the Quartermaster and Signal Corps, which also had substantial procurement and contracting responsibilities, managed with far fewer procurement offices in the field. The Signal Corps had 3 and the Quartermaster Corps had 28. The chief was understandably concerned to have experienced personnel in place once postwar civil works construction began.

As the war progressed, the maintenance of equipment became increasingly important. Under the technical supervision of the Supply Division in the Office of the Chief of Engineers, maintenance responsibility was delegated to the Engineer Field Maintenance Office in Columbus, Ohio, and seven regional maintenance offices located at various depots. Shops located at 16 depots, supplemented by government-owned and contractor-operated commercial shops under the jurisdiction of division engineers, performed difficult maintenance on engineer troop equipment. The regional maintenance offices provided specialized assistance to troops, depots, ports, and other supply agencies in the preventive maintenance, repair, and packing of equipment. In fiscal year 1944, the responsibility for the supervision and operations of the regional offices was transferred to the division engineers, who sometimes further decentralized this function to district engineers.

Several committees and boards reported to the Chief of Engineers. These included the Engineer Board at Fort Belvoir and the Board of Engineers for Rivers and Harbors (BERH). The BERH, established in 1902, continued during the war

to execute its congressionally mandated responsibility to review rivers and harbors reports emanating from the field offices. It also continued to compile statistics on waterborne commerce in the United States, prepared a "Port Series" on U.S. ports, and collaborated with the Military Intelligence Division in the Office of the Chief of Engineers on preparing studies of foreign ports for inclusion in the division's wartime "Strategic Engineering Studies."

The Engineer Board at Fort Belvoir and its various test branches developed and tested engineer equipment and developed field doctrine for the use of the equipment in the field. The major types of equipment procured by the engineers and serviced by engineer troops included floating and fixed bridges, heavy construction equipment, camouflage materials, antiaircraft searchlights, barrage balloons (before 1942 handled by the Air Corps), airfield landing mats, demolition equipment, water purification and distributing equipment, firefighting equipment, mobile shops, field fortification supplies, and gasoline and fuel-dispensing equipment. The Engineer Board would occasionally call upon Corps civilian engineers and on the expertise at the Waterways Experiment Station for assistance in evaluating and designing new equipment. As already mentioned, engineer replacement training centers and unit training centers, all under the jurisdiction of the service commands, provided engineer training. However, they followed doctrine prepared in the Office of the Chief of Engineers.

The Beach Erosion Board, which was established in 1930, continued its studies of coastal erosion problems around the United States. However, it also collaborated with the Military Intelligence Division to prepare studies on foreign beach and port areas for the division's "Strategic Intelligence Studies." Finally, a short-lived group called the Art Advisory Committee existed for a few months in 1943. The committee was established to advise the Chief of Engineers on measures to promote the painting of wartime battle scenes and other related subjects. It made recommendations on the recruitment of civilian, military, and overseas artists.

During World War II, military and civilian officials from the Office of the Chief of Engineers served on a number of committees outside of the Corps of Engineers. These included

the Highway Traffic Advisory Committee and its successor, the Joint Action Highway Board. Headed by the Public Roads Commissioner, these committees advised on the routing of Army troop movements and military supply traffic over public roads in the United States. Other committees on which the Corps was represented included the National Civil Technological Protection Committee and the War Production Board's Facilities and Construction Committee.

The Army Corps of Engineers faced major challenges during World War II in procuring and distributing engineer equipment, expediting construction of major installations, and fulfilling the ongoing mission of keeping United States rivers and harbors maintained for both commercial and national defense purposes. These responsibilities had to be fulfilled while time, manpower, and seasoned officers were in short supply. Although there were certainly major frustrations, and organizations were occasionally jury-rigged to respond to immediate exigencies, by the end of the war the Corps had earned increased respect from both military and civilian agencies. Innovation, responsiveness, flexibility, and decentralization were key elements in the engineers' success.

Sources for Further Reading

The most important source for this essay was a master's thesis by Mabel E. Deutrich entitled "The Office of the Chief of Engineers During World War II" (American University, 1950).

Other sources included Blanche D. Coll, Jean E. Keith, and Herbert H. Rosenthal, *The Corps of Engineers: Troops and Equipment, United States Army in World War II: The Technical Services* (Washington, DC: Office of the Chief of Military History, Department of the Army, 1958); General Service Administration, National Archives and Records Service, *Federal Records of World War II: Military Agencies*, Volume II (Washington, DC: National Archives and Records Service, 1951); and James E. Hewes, Jr., *From Root to McNamara: Army Organization and Administration, 1900–1963, Special Studies* (Washington, DC: Center of Military History, United States Army, 1975).

The Office of History, Headquarters, U.S. Army Corps of Engineers, has in its research collection a number of organization charts from the World War II era, and the Headquarters library holds Engineer General Orders pertaining to the establishment and disestablishment of engineer field agencies during the war.

The Air Corps Construction Mission

by Charles Hendricks

The agreement by the leaders of Britain and France in Munich at the end of September 1938 to accede to Adolf Hitler's ultimatums and permit him to dismember the democratic state of Czechoslovakia brought home to America's political leaders that Europe's democracies lacked the strength by themselves to stem the expansion of a militarily resurgent Germany. William Bullitt, U.S. Ambassador to France, reported to President Franklin Roosevelt the next month that the French were particularly overawed by the German bomber fleet, which had grown substantially larger than that of Britain and France combined. The U.S. Army Air Corps, which then possessed only some 1,600 planes, had similarly lagged behind German air power.

In the aftermath of Munich, President Roosevelt moved quickly to overtake German production of airplanes. Summoning his leading military and civilian advisers to the White House in mid-November, Roosevelt observed that "our national defense machine. . .was weakest in Army planes." Setting an ambitious goal of an air force of 10,000 planes and a national productive capacity of 10,000 planes per year, the President, still hoping to avoid unnecessary involvement in a European war, explained that "we must have a large air force in being to protect any part of the North or South American continent."

The defense appropriation requests which the President delivered to Congress in January 1939 reflected his desire for an early expansion of the air arm, although not yet to the goals enunciated two months earlier. Of the $1 billion he sought for both routine and extraordinary defense needs, $300 million was earmarked to expand the Air Corps by 3,000 planes. Some $62 million of that sum was sought for air base construction with the largest sums designated for projects in the Canal Zone. Congress approved the administration's defense requests in appropriation bills passed in April and July.

The Army Quartermaster Corps had earlier in the century added military airfield construction to its traditional tasks of building and furnishing the barracks and other buildings in which Army soldiers and officers lived and worked. The military construction responsibility of the Quartermaster Corps had been questioned during World War I, as General John Pershing assigned construction duties in France to his engineers and the War Department created an independent Construction Division of the Army to oversee military base construction in the United States. Congress had restored the domestic military construction function to the Quartermaster Corps in the National Defense Act of 1920. But when, in the spring of 1939, the nation embarked on a program to expand its air power, the War Department, concerned about the ability of the Quartermaster Corps to handle the entire military facilities development program, considered a transfer of responsibility for domestic airfield construction to the Corps of Engineers.

General George C. Marshall played an important role in arranging the transfer of the Air Corps construction mission to the Corps of Engineers.

Assistant Secretary of War Louis Johnson and Army Deputy Chief of Staff Brigadier General George Marshall led the initial effort to reassign domestic airfield construction to the Corps of Engineers. They obtained from President Roosevelt an expression of support for the shift, providing it could be effected without congressional opposition. Seeking to accomplish the transfer without recourse to new legislation, proponents first focused on the provision of the 1920 law that gave the engineers responsibility for the construction of fortifications. Observing that "in order to expedite our defense program, it may be necessary to have the Corps of Engineers construct the Air Corps installations," Brigadier General George Tyner,

the Army's chief logistics officer, asked Major General Allen Gullion, the judge advocate general, whether runways and hangars, as distinct from airfield barracks, could be classified as fortifications. Gullion agreed that such an interpretation would be possible. But despite the apparent preferences of his War Department superiors, Tyner could not endorse such an administrative nightmare as dividing responsibility for the construction of airfield operating and housing facilities.

The Reorganization Act of April 1939 made such awkward interpretations unnecessary by permitting administrative transfers without prior legislative approval. Secretary of War Harry Woodring quickly suggested the transfer of all of the military construction functions of the Quartermaster Corps to the Corps of Engineers under this authority. Tyner strongly endorsed this more sweeping concept, observing that "construction is a specialized type of engineering, and as such, should naturally fall within the duties of a technical branch rather than a supply branch." He predicted that "the Corps of Engineers. . .will bring to this activity a standard of efficiency not possible under the existing setup."

Major General Robert Beck, the department's senior operations and training officer, objected, however, fearing that assigning this duty to the engineers might reduce their readiness for combat. Beck also recognized that Major General Julian Schley, the Chief of Engineers, was prepared to accept responsibility for the construction but not for the maintenance of Army land and air facilities, and Beck believed that such a division would be unwise. Lacking united War Department support for the transfer, Woodring chose to retain the Quartermaster Corps as his department's agent for constructing domestic land and air facilities in the early months of American mobilization.

The German invasion of Poland in September 1939 and the resulting declaration of war by Britain and France did not immediately produce a rapid expansion of the American mobilization effort that was already underway, but they did hasten the Army's internal reorganization for war. The War Department asked the Chief of Engineers to develop plans for engineer troop units that could build the airfields that would be needed for any foreign deployment of the Army Air Corps. In response, Brigadier General John Kingman,

Assistant Chief of Engineers, Military Division, proposed the creation of an engineer aviation regiment of three battalions with a peacetime strength of 43 officers and 1,050 men. The unit would train with Air Corps personnel in "hasty methods" of rehabilitating captured airfields or "improvising new ones." The first unit of this type, the 21st Engineers, was organized from a newly activated general construction unit in June 1940.

The dramatic German military victories of the spring of 1940, culminating with the capitulation of France in mid-June, led to a rapid increase in American defense preparations. At the President's request, Congress passed in the next five months an initial War Department appropriation and three omnibus supplemental defense appropriations totaling more than $9 billion. Congress appropriated more than $780 million for the construction of Army installations and airfields in this period. Even these large sums, however,

Built by the Quartermaster Corps, Hamilton Field, north of San Francisco, California, was already in use in January 1941.

were inadequate for the extensive building program which the War Department ordered an overburdened Quartermaster Corps Construction Division to complete by the time conscripts would arrive the following spring.

The German victories and a May presidential veto of a new rivers and harbors authorization bill convinced General

Schley that military construction would soon supersede navigation and flood control projects as the federal government's largest engineering assignment, and he sought to redirect his department's efforts accordingly. Observing to newly appointed Assistant Secretary of War Robert Patterson in the summer of 1940 that his rivers and harbors "work was drying up," Schley argued that his civil works organization was much better suited to direct the rapidly expanding military construction effort than was the Quartermaster Corps. As it turned out, Corps of Engineers civil works expenditures would remain quite steady through 1943.

The congressional friends of the Corps of Engineers, some of whom had already expressed a willingness to sponsor a transfer of the construction mission to the Corps, now acted to facilitate the Army's use of its engineer construction organization. On 5 August 1940, Senator John Miller of Arkansas announced that he would introduce an amendment to a pending rivers and harbors authorization bill which would empower the Secretary of War to assign any part of the nation's defense construction tasks to the Corps of Engineers. Convinced by Schley's appeal and understanding that General Marshall, now Army Chief of Staff, also supported the measure, Patterson endorsed Miller's rider ten days later and urged him to attach it to the second supplemental defense appropriation bill, which was heading for quick passage.

A more senior senator, Kenneth McKellar of Tennessee, actually proffered the amendment as the Senate debated the appropriation on 29 August. The rider won quick approval, gained conference committee support after General Marshall warmly endorsed it before that group, and then passed the House, albeit in modified form. The House insisted that the authority granted to the Secretary of War to transfer construction functions to the Corps of Engineers expire in mid-1942. The Senate quickly acceded to this change, and the provision became law on 9 September 1940.

Once the War Department possessed explicit authority to transfer construction responsibilities to the Corps of Engineers, Patterson assigned his special assistant Major Sidney Simpson, a reserve field artillery officer, to evaluate the Construction Division's handling of its growing workload. Simpson found that the division suffered from persistent

personnel shortages and administrative difficulties. However, he did not propose that the division's tasks be turned over to the Corps of Engineers; rather he simply concluded that the Construction Division was caught in "a straight-jacket organizational setup in the Quartermaster Corps," and believed its problems could be resolved if it were placed directly under Patterson and perhaps renamed "the Construction Corps."

Knowing that incoming Secretary of War Henry Stimson's close associate Benedict Crowell, who had been Assistant Secretary of War during World War I, favored reviving the independent Construction Division utilized at that time, and seeing Major Simpson's Construction Corps as remarkably similar, a group of high-ranking officers and War Department civilians now acted to keep the Corps of Engineers in the picture by asking that Air Corps construction be transferred to the Corps of Engineers. The leaders in the effort were Michael Madigan, a self-made millionaire engineer contractor and top civilian assistant to Patterson, and two career Corps of Engineers officers now holding top Army staff positions: Deputy Chief of Staff Major General Richard Moore and Brigadier General Eugene Reybold, the Army's top supply officer.

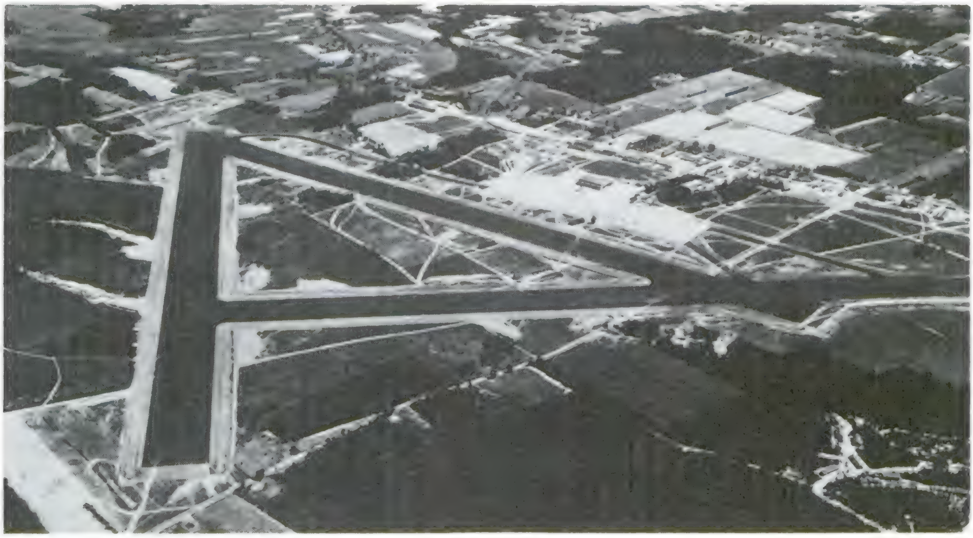
Although he had supported such a transfer at the start of mobilization, Marshall expressed serious misgivings about it in late 1940 with the construction program in full swing. However, he decided that he "had to quickly reduce the load on the Quartermaster Corps" and so agreed. The transfer would move about 40 percent of the construction workload, figured in sums expended, and a somewhat smaller proportion of the manpower requirements from the Quartermaster Corps to the Corps of Engineers.

With Stimson's approval, Reybold issued the Air Corps construction transfer order on 19 November 1940. It covered work at all Air Corps stations in the United States and its possessions except in the Canal Zone, where air and land base development contracts had not been segregated. Schley assigned supervision over Air Corps construction to Assistant Chief of Engineers Brigadier General Thomas Robins and the Civil Works Division he had led since 1939. With its expanded mission, the division dropped "Civil Works"

on Pearl Harbor and the formal entry of the United States into the war. During that year the Corps of Engineers oversaw some $400 million of Air Corps construction work in the United States and its territories, more than five times the amount handled by the Quartermaster Corps in the previous year and a half. By comparison, the civil works expenditures of the Corps of Engineers in this period averaged just over $200 million annually.

Construction progress on a hangar and control tower at Paine Field near Everett, Washington, October 1941. This was one of the many smaller airfield projects the Corps completed during World War II.

In the continental United States during 1941, the Corps of Engineers developed 42 new airfields, complete with housing and technical facilities, and added similar facilities to an equal number of municipal airports which the Air Corps had arranged to use. The largest of the new fields, on each of which the Corps spent $13–15 million in the year before the United States entered the war, were the Keesler and Sheppard fields in Biloxi, Mississippi, and Wichita Falls, Texas, respectively, each of which was designed to house more than 24,000 troops. The engineers expanded facilities at 25 existing Air Corps stations. They also built new aircraft assembly plants at Fort Worth, Tulsa, Kansas City, and Omaha, and an Air Corps Replacement Center at Jefferson Barracks in St. Louis.



Bradley Field, Windsor Locks, Connecticut, where Providence District of the Corps of Engineers used camouflage techniques to disperse and disguise airfield facilities, 28 August 1941.

With a pre-existing organization of 10 engineer divisions overseeing 45 engineer districts across the country and an administrative policy that granted its regional officials far more decision-making authority than did the Quartermaster Corps, the Corps of Engineers was able to respond quickly and efficiently to the rapidly expanding Air Corps construction program. Experienced in obtaining competitive bids from private contractors, the Corps accomplished its airfield work in 1941 with more than twice the rate of competitive fixed-price contracting than had the Quartermaster Corps. The engineers also developed innovative responses to shortages of materials and money, including timber-frame hangars and sturdy asphalt runways.

By mid-1943 the Corps of Engineers had completed some 1,100 domestic military and civil airfield projects. General Henry Arnold, Commander of the Army Air Forces, commended the Corps for its work on the airfield construction program which, he observed, had "been prosecuted with outstanding efficiency and dispatch." He quoted the remark of his subordinate responsible for the training of heavy bomber crews, Major General Davenport Johnson: "The Second Air Force has some of the finest airfields in the world." Quality airfield construction, both in the continental

United States and abroad, proved to be one of the most important contributions to Allied victory in World War II made by the Corps of Engineers.

Sources for Further Reading

The Corps of Engineers: Construction in the United States (Washington, 1972) by Lenore Fine and Jesse Remington narrates in considerable detail the story of the assumption and execution by the Corps of Engineers of the domestic Air Corps construction mission in World War II and the engineers' related research efforts.

Stetson Conn and Byron Fairchild's *The Framework of Hemisphere Defense* (Washington, 1960) and Mark S. Watson's *Chief of Staff: Prewar Plans and Preparations* (Washington, 1950) describe the strategic context in which the decision to give that mission to the engineers was made.

W. F. Craven and J. L. Cate's *The Army Air Forces in World War II*, Volume 7: *Services Around the World* (Chicago, 1958) discusses the wartime construction of overseas air bases by American aviation engineers.

Building the Atlantic Bases

by Charles Hendricks

The rapid German military victories in western Europe in the spring of 1940 isolated Great Britain as the sole remaining European combatant opposing Hitler's military machine. The capitulation of France and the installation of the fascist Vichy regime there in June ended a season in which German armies had also occupied and overthrown the democratic governments of Denmark, Norway, the Netherlands, Belgium, and Luxembourg. Only the survival of British arms, including the maintenance of its dominant naval power, separated the advancing German forces from possible inroads in the New World.

Heavy air attacks on Britain in the summer of 1940 raised the specter of a German assault on that island. Such an assault, if successful, would leave American security interests in the western hemisphere gravely exposed. While the British proved more tenacious in the face of this onslaught than Americans had at first anticipated, there was still cause for concern. The defeat in September of a combined British and Free French attack on Vichy land and naval forces in the French West African port of Dakar made the German menace to the not-so-distant eastern bulge of South America all the more vivid.

Despite the growing threat to American security posed by these developments, the American public and its elected leaders sought to avoid direct involvement in the European combat. Americans were still disillusioned from another European conflict two decades earlier—one which President Woodrow Wilson had described as "a war to end all wars." Thus, while Congress in mid-1940 approved large new appropriations for American military mobilization, it forbade the administration to sell any American ships, weapons, or munitions of war unless it could certify them as nonessential to the defense of the United States. At the time, many Americans feared that Britain, like France, might capitulate to the Germans and that American munitions

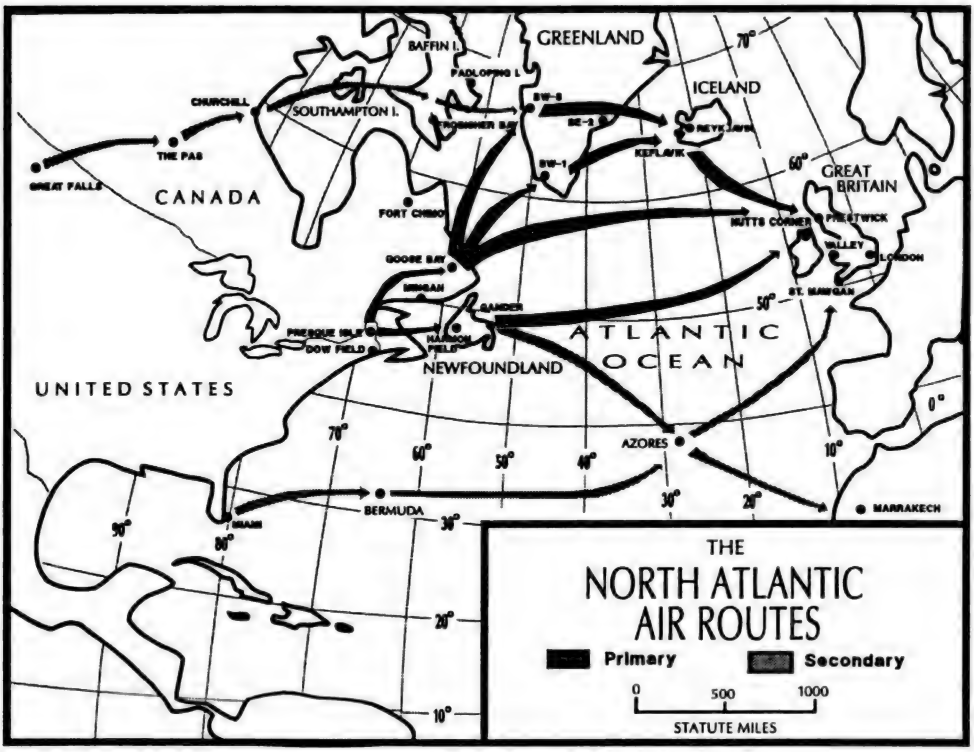
purchased by the British might then be turned against the United States.

Adopting a more optimistic approach, President Franklin Roosevelt wanted to respond positively to British Prime Minister Winston Churchill's plea in July 1940 for some American destroyers and other naval boats and planes. Taking up a suggestion made by a New York group supporting aid to Britain, the administration proposed the exchange of 50 aging destroyers for the right to establish American naval and air bases in seven British possessions in the western hemisphere. These possessions formed an arc from Newfoundland in the north to the South American territory of British Guiana and included the island possessions of Bermuda, the Bahamas, Jamaica, Saint Lucia, and Trinidad. Diplomatic notes exchanged on 2 September by the American and British foreign secretaries effected accords along those lines, including a British promise never to surrender the warships to the Germans and provisions for 99-year American leases on its new bases. The destroyer-base agreement, which proved broadly popular in the United States, expanded the bonds of British and American strategic cooperation and provided the United States with new opportunities to develop forward lines of defense in the Atlantic.

Although the War Department had yet to transfer responsibility for air base construction in the United States from the Quartermaster Corps to the Corps of Engineers, Army Chief of Staff General George Marshall immediately assigned the work in the British territories to the engineers. In October, Chief of Engineers Major General Julian Schley began to create the organizational structure to handle the new assignment. He named Lieutenant Colonel Joseph Arthur, an experienced manager of Corps civil works projects, as engineer of the new Eastern Division, which he placed in overall charge of the new work. Reporting to the Eastern Division would be the Newfoundland and Bermuda Districts, headed by Majors Philip Bruton and Donald White, respectively. In December 1940 new Jamaica and Trinidad Districts were added to the Eastern Division to oversee the work required in the Caribbean.

Before much construction could begin at the sites contemplated in the destroyer-base accord, the Corps obtained

a further base construction responsibility beyond the nation's borders. Using authority contained in a June military appropriation act, the War Department on 2 November 1940 entered into a secret contract with Pan American Airways to build or expand commercial airfields in Central and South America and the Caribbean in accord with War Department specifications. Under the contract, the U.S. government would provide full funding for the work, and a Corps of Engineers officer would oversee the project from the United States. The fields would be designed to accommodate both commercial and military planes, but the use of a commercial airline as construction agent obviated any need for formal military understandings with the host nations.



North Atlantic Air Routes

The danger that German military forces might advance in the North Atlantic from Norway to the former Danish territories of Iceland and Greenland worried both Churchill and Roosevelt. In May 1940, soon after the German conquest of Denmark, Britain occupied Iceland. The United States

acted to protect the North Atlantic the following year. On 9 April 1941, Secretary of State Cordell Hull signed a defense agreement with Free Danish authorities under which the Americans guaranteed the security of Greenland in exchange for broad authority to construct air bases and other facilities on the island. Americans feared in particular that a German attack on the cryolite mine at Ivigtut in southern Greenland would disrupt the supply of a metal crucial to the production of Canadian aluminum, which American aircraft manufacturers needed to build planes. Hoping to free British forces in Iceland for more pressing military requirements elsewhere, the United States also accepted on 1 July 1941 Iceland's invitation to take over its defense. Engineer troops initiated American base construction efforts on both Iceland and Greenland.

Base construction in the harsh climates of the North Atlantic, where ice and snow could interfere with winter work and supply, generally proved more difficult than did the construction jobs in the island and mainland territories to the south, but the engineers pursued the northern work with no less vigor. Major Bruton arrived on Newfoundland in mid-October 1940 and, using local workmen, quickly began building temporary housing outside Saint John's, the island colony's capital. Construction began at Fort Pepperrell, destined to become the major American installation protecting that city, in the last days of 1940. Located on a rocky coastal hillside, the post would eventually accommodate 5,500 troops. In March 1941 work got under way at Fort McAndrew, located 80 miles to the west across the Avalon peninsula. This post protected the large air and sea base that the U.S. Navy built at nearby Argentia.

At the war's outset, Newfoundland's Gander Field appeared adequate to meet the needs of both Canadian and American military aircraft. The Canadians operated this field during the war, although U.S. troops assisted with maintenance. The Corps of Engineers supplemented Gander by building Harmon Field at Stephenville on Newfoundland's west coast. Originally planned as an emergency landing field, the site was expanded beginning in 1942 into a permanent field with facilities for 2,800 troops and four tanker anchorages. The Air Corps judged Harmon to have 10 percent

Pavers work both ends of a 25-foot-wide slab on Runway 2 at Harmon Field on Newfoundland's west coast.

clearer weather than Gander, and it eventually became the primary American air ferry landing site on the island.

Beginning in April 1941, a consortium of four American contractors led by two Minnesota firms undertook the bulk of the Newfoundland work. In a pattern typical of Atlantic base construction efforts, the contractors recruited most of their labor locally but imported the bulk of the materials they used from the United States. An administrative shift occurred in June 1941 when the Eastern Division was reorganized as the Caribbean Division and the Corps of Engineers placed the Newfoundland District under the North Atlantic Division. By the time the Corps' construction efforts in Newfoundland were completed in April 1943, the cost of its projects there amounted to $60.3 million, including $750,000 worth of materials lost at sea.

Elements of the 21st Engineers, the Army's first specialized airfield construction regiment, initiated base construction in both Iceland and Greenland. Engineer troops arrived in Greenland in July 1941 with the first shipment of United States forces there, and they initially concentrated on erecting housing and anchorage facilities. The arrival in September of civilian construction crews provided by two of the contractors already at work in Newfoundland enabled the

Planes parked at Bluie West 1 Airfield, the Army's primary Greenland base, July 1942.

engineer troops to concentrate on the construction of the primary Greenland field, code named Bluie West 1, located at the head of a fjord in the southwestern part of the island. That winter, troops and civilian workers alike lived in prefabricated buildings erected a few feet off the ground. Twelve-seat latrines, blasted out of the frozen soil and sanitized weekly by spraying with oil and igniting, served each company. Fortunately, the civilian workers had been recruited from an office in northern Wisconsin and were accustomed to cold winter weather.

By 1943 the field at Bluie West 1 would include a 6,500-foot concrete runway and a 5,000-foot asphalt strip. As early as September 1941, however, troops began laying pierced-steel landing mat on a 3,500-foot temporary runway, an early use of this technology. The companies of the 21st Engineers in Greenland sailed back to the United States in June 1942, and civilian crews replaced them. Directed first by North Atlantic Division area engineers and then, after December 1942, by a new Greenland District, the contract workers also built the Bluie West 8 field on Greenland's west coast just north of the Arctic Circle and the Bluie East 2 field on the island's eastern coast at Iceland's latitude. Construction progressed year-round despite delays caused by shipping

Bluie East 2 Airfield nestled at the foot of Greenland's eastern coastal range.

problems and winter storm winds which reached 165 miles per hour. By the end of 1943, the Army had 5,300 troops in its Greenland garrison.

While the elements of the 21st Engineers that landed in Iceland in August 1941 comprised the first Army engineer contingent there, they arrived a month after a 4,100-man U.S. Marine force. The Americans joined a 24,000-man British garrison that had already met its housing needs and developed air bases at Reykjavik, the capital, and Kaldadharnes, 35 miles to the southeast. The 41 bombers and 9 fighters at these fields protected the island and adjacent Atlantic shipping lanes, but when 30 American planes joined them in August 1941, the fields became decidedly crowded. The air strength was essential, however, for Iceland lay within range, albeit barely, of the 60 to 90 German bombers based in Norway.

Iceland Base Command Engineer Lieutenant Colonel Clarence Iry directed both Army and Marine troops in erecting the housing that would be needed by a rapidly growing American garrison. He was aided in 1941 by the British contribution of some corrugated-iron-roofed Nissen huts and the contract labor needed to erect them. His task was further eased the following year when the British evacuated almost

all of their garrison, leaving their housing behind. However, as American troop strength in Iceland grew by early 1943 to 41,000, roughly double the size of the departing British contingent, additional building was required.

As elsewhere in the Atlantic, the engineers' most important task in Iceland was airfield construction. Finding the existing fields too small for the volume of air traffic expected and unsuitable for heavy B-24 bombers, the 21st Engineers began in 1942 the construction near Keflavik of the new Meeks Field for bombers and an adjoining fighter base, Patterson Field. American civilian construction workers joined the effort in May, but they were replaced by two Navy construction battalions later in the year. The fighter base progressed quickly, and two of its three runways could accommodate the Eighth Air Force fighter planes that landed in Iceland en route to Britain in July 1942. Meeks Field opened the following March with the landing of a B-18 carrying Iceland Base Commander Major General Charles Bonesteel. Paving was complete at both fields by August 1943. U.S. Army engineers also expanded the asphalt runway at the British-built field near Akureyri, Iceland's second largest population center located on the north side of the island, making it available to medium bombers.

Despite the heavy workload, engineer soldiers who spent several years in Iceland grew tired of their isolation and bleak surroundings. The officers of one engineer battalion sought to combat the soldiers' boredom by issuing an ample supply of harmonicas.

Soon after the United States entered the war, the War Department decided to deploy Major General Carl Spaatz's Eighth Air Force to Britain. This put the North Atlantic facilities constructed by the Corps to an early test. Radioing from Bluie West 1 in Greenland while crossing the Atlantic in mid-June 1942, Spaatz ordered the movement to begin. The P-38 and P-39 fighters, piloted by combat crews that had been given special training in long-distance flying, were escorted by the longer-range B-17 bombers. With stops at the Canadian-built base at Goose Bay in Labrador, Bluie West 1 in southern Greenland, and Reykjavik or Keflavik in Iceland, the planes could fly from the new Presque Isle field in northern Maine to Prestwick Field in Scotland with no leg of the journey longer than 850 miles.

Use of the northernmost Bluie West 8 field in Greenland involved a 1,000-mile hop from Goose Bay but provided an alternate landing site when the weather was bad in southern Greenland. A few planes arrived at Bluie West 8 from the Western U.S. via the Crimson route, a line of fields stretching from Manitoba to Baffin Island in northern Canada that the Canadians and the North Atlantic Division of the Corps built in 1942 and 1943. All told, 920 warplanes attempted the North Atlantic crossing during 1942, and with the aid of the fields built by the Corps, 882, or roughly 95 percent, arrived safely. Air ferry traffic peaked in 1944 when some 5,900 planes successfully crossed the North Atlantic.

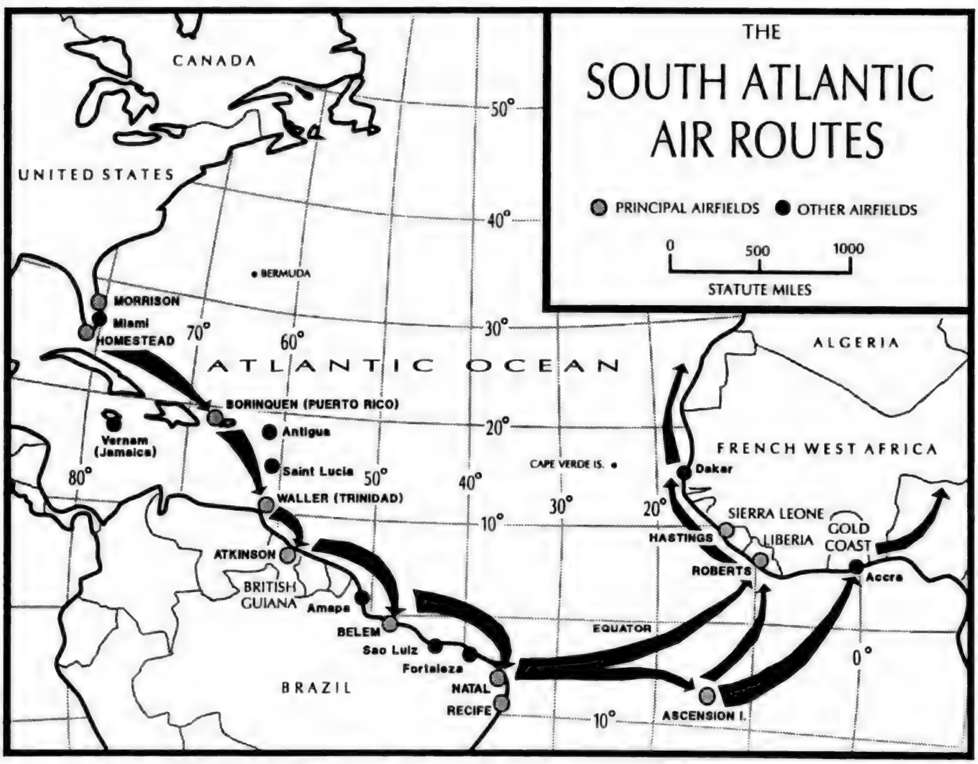
Bermuda, a small British island territory located just 600 miles off the North Carolina capes, anchored the center of the United States' Atlantic defenses. The dearth of land on the 21-square-mile island group led the Corps to build Kindley Field on some 29 million cubic yards of dredged coral

Kindley Field, Castle Harbor, Bermuda, built primarily on dredge fill, April 1942.

and fill in Castle Harbor. A contractor's dredge boat began work in March 1941 and Jacksonville District's hydraulic dredge *Welatka* joined the effort that summer. While an emergency runway was ready by July 1941, the contractors did not complete the last of the three permanent runways,

which were 8,300; 5,800; and 5,000 feet long, respectively, and the field's supporting facilities until August 1944. The contractors, who employed some 3,000 workers on Bermuda, also built housing facilities for 2,700 men at the 270-acre Fort Bell and for another 625 at the U.S. Navy's new Bermuda naval air station. While Kindley Field quickly became one of the Corps' largest Atlantic airfield projects, it was not used at first as an air ferry station due to Portugal's refusal until December 1943 to permit Allied planes to land in the Azores.

Like the North Atlantic bases, the facilities built by the Corps in the Caribbean and South America supported both the military security of those areas, challenged early in the war by German submarines, and the ferrying of aircraft across the Atlantic. American airfield construction began in the British possessions of Antigua, Saint Lucia, Trinidad, and British Guiana in January and February 1941 and in Jamaica in May. The Corps also assumed responsibility for the construction of Borinquen Field, Puerto Rico, from the Quartermaster Corps in January 1941. Unlike Greenland and Iceland where engineer troops would initiate work that



South Atlantic Air Routes

summer, civilian contractors undertook the major Caribbean construction tasks from the start.

The island of Trinidad, strategically positioned just north of Venezuela at the southern gateway to the Caribbean, received the largest wartime Army construction effort in the region, outside of the Canal Zone. Waller Field and the adjoining Army post of Fort Read, occupying a 17,000-acre tract in the interior of the island, became the principal Army base in Trinidad. After removing a thick canopy of jungle vegetation, crews of the Walsh Construction Company and the George F. Driscoll Company opened a temporary runway on Waller Field in the summer of 1941 and two mile-long concrete runways the following January and June. They also erected housing for 8,500 men and 51 aviation-fuel storage tanks. The heavy demand for local labor caused by this project and the simultaneous construction of a large Navy facility on the island led the Corps contractors to import 2,000 workers from the neighboring island of Barbados.

While the $52.4 million Waller Field was the most expensive Atlantic base built by Corps contractors, it did not meet all the needs of the burgeoning Trinidad garrison. The Corps thus had its Trinidad contractors begin work in December 1941 on a 5,000-foot runway at Edinburgh Field 12 miles to the southwest and in 1942 on a similar runway at adjoining Xeres Field. They completed the new runways in June 1942 and April 1943. Engineer contractors also oversaw the construction of coast artillery positions and base facilities at Chacachacare and Monos islands between Trinidad and Venezuela. The Caribbean Defense Command took over supervision of the Trinidad and Jamaica Districts in April 1942, leading the Corps to abolish its Caribbean Division at that time.

Construction of $10–16 million fields in the other British sites in the Caribbean followed largely similar timetables, with Corps contractors opening temporary runways in Antigua, Saint Lucia, and British Guiana in June 1941 and concrete runways the following year. A Minneapolis firm completed two mile-long concrete runways at Antigua's Coolidge Field by September 1942, but the area engineer there directly hired the workers who built the housing for 2,200 men completed the following May. Minder Construction

of Chicago finished the two 5,000-foot concrete runways at Beane Field near the African-American community of Vieux Fort, Saint Lucia, even more quickly, opening them in February and April 1942. The engineers at Saint Lucia made full use of locally available materials, employing molasses as a stabilizing agent for the surface of the temporary runway.

While work on the other islands proceeded smoothly, progress at Vernam Field on Jamaica lagged. The Jamaica district engineer found the joint venture responsible for the first year's construction there to be inefficient and in April 1942 replaced it with the McLane Corporation. Three runways, a 6,000-foot concrete strip and two roughly mile-long asphalt runways, formed the center of this field designed to house a heavy bombardment squadron.

Local workmen construct a runway at Atkinson Field, British Guiana. (U.S. Air Force, National Air and Space Museum, Smithsonian)

The relatively large Atkinson Field, located 26 miles south of British Guiana's capital of Georgetown, included housing for 4,000 men, three permanent hangars, and a 7,430-foot main concrete runway. A lack of adequate land transportation routes hampered the construction effort. Boats carried rock for the project downstream from a quarry 75 miles up the Demerara River, and other construction supplies came upstream from Georgetown.

The United States added several bases in the Caribbean area after it entered the war. Under agreements negotiated with the exiled Netherlands regime, U.S. Army ground and air troops went to Surinam in November 1941 and to the Dutch Caribbean islands of Curaçao and Aruba off Venezuela in February 1942. Using the Walsh–Driscoll joint venture, the Trinidad district engineer expanded Zandery Field in Surinam, which Pan American had built in 1941, and had the KLM runways at Hato Field on Curaçao and Dakota Field on Aruba resurfaced and extended to 5,000 feet, roughly doubling their length. In June 1942, Cuba furnished a 2,000-acre tract 30 miles southwest of Havana, and the Cayuga Construction Company, under contract with the Corps' North Atlantic Division, built Batista Field there. The $17.4 million air base featured two 7,000-foot runways and housing for 3,500 men. A final Atlantic base site was added in March 1943 when the governor of French Guiana shifted his allegiance to the Allies and invited American troops into the territory. During the next ten months, the Trinidad district engineer had a 6,000-foot concrete landing strip built at Rochambeau Field in that territory at the behest of the commander of U.S. Forces, South America. Fifty emergency landings would be made at this field during the last year and a half of the war.

The airfields that Pan American constructed in northern Brazil formed, with the Caribbean bases, an essential link in the South Atlantic air ferry route. Construction began at Amapá, Belém, and São Luís in the underdeveloped regions near the mouth of the Amazon in the spring of 1941. At São Luís, teams of oxen hauled away uprooted trees and 1,000 burros carried off dirt in raffia panniers. Work began that summer at Natal and Recife on Brazil's eastern tip, but with labor and equipment more readily available there, it progressed more rapidly. Prior to March 1942 when Brazil first authorized the Corps to send Lieutenant Colonel Manuel Asensio to oversee Pan American's work from within the country, the commercial firm received only such Corps support as its offices in New York and Washington could provide. Federal funds allotted to this work, moreover, were meager. Nonetheless, by the time of Asensio's arrival, Pan American had readied a good 5,000-foot runway at Natal,

Local workers complete the thatched roof of enlisted men's barracks at Roberts Field, Liberia, May 1943. *(U.S. Air Force, National Air and Space Museum, Smithsonian)*

in 1941 to build an additional airfield in Liberia. Pan American received the contract to build Roberts Field adjacent to a large Firestone rubber plantation 50 miles east of Monrovia, the Liberian capital, but it subcontracted most of the work to the Firestone Plantation Company. By early 1943 a largely Liberian workforce had laid two 7,000-foot paved runways in an area previously covered by thick jungle vegetation.

Early in 1942 Britain authorized the United States to build an airfield on Ascension Island, a 34-square-mile mass

A Martin B-26 Marauder at Wideawake Field on bleak Ascension Island, May 1943. ***(U.S. Air Force, National Air and Space Museum, Smithsonian)***

of volcanic rock that pierced the surface of the South Atlantic conveniently close to the midpoint of the flight from Natal to Africa. Colonel Robert Coughlin brought his 38th Engineers to the island in February 1942 to build Wideawake Field. One of his battalion commanders was Major Frederick Clarke, a future Chief of Engineers. Carrying supplies and equipment to shore by barge or lighter on this harborless island, the regiment began construction of the 6,000-foot runway in mid-April and opened it to traffic three months later.

Soldiers on Ascension Island could use scarce potable water for drinking and washing, but not for laundry. *(U.S. Air Force, National Air and Space Museum, Smithsonian)*

A large tern rookery at the end of the runway posed a real threat to air traffic at Ascension Island, however, as takeoffs flushed huge flocks of birds into flight paths. Air transport officers used smoke candles, dynamite blasts, and a planeload of cats in a series of unavailing efforts to convince the terns to relocate—strong-beaked booby birds on the island, the officers learned, found the cats an appetizing treat. Only the destruction of some 40,000 eggs at the suggestion of ornithologist James Chapin, whom the Air Force finally brought in from the American Museum of Natural History,

induced the birds to leave the runway area and join other colonies on the island. The engineers derived some value from the birds, however, as they used guano bricks in the construction of installation housing.

The South Atlantic air route from Miami, Florida, to the Middle East, using fields in the Caribbean, Brazil, and Africa, opened in September 1941 when Lieutenant Colonel Caleb Haynes used it to fly a B-24 carrying Major General George Brett, Chief of the Air Corps, to Cairo, Egypt. Although this trip covered roughly 10,000 miles, far longer than the 2,700-mile North Atlantic route from Maine to Scotland, the better weather on the southern route and its easier access to the busy theaters of operations in the Mediterranean, Eastern Europe, and Asia led it to carry more air traffic across the ocean than did its northern counterpart in the early years of the war.

After the Japanese disrupted the Pacific air supply route passing through Midway and Wake islands in the autumn of 1941, the Air Corps routed airplanes destined for the Far East over the South Atlantic, Africa, and South Asia to Australia. The Japanese seizure of Singapore in February 1942 broke the connection, however, and made a South Pacific route essential. Thereafter, planes ferried across the South Atlantic reached destinations in China, India, the Soviet Union, and the Mediterranean. When winter weather closed the North Atlantic air route, planes that had crossed the Atlantic from Brazil went on to Britain from North Africa.

The Air Corps used the South Atlantic air ferry route in 1942 to deliver 240 planes to the Soviets under the American lend–lease program. The nearly two dozen B-24Ds which began the Air Corps' European combat with a June 1942 bombing raid on Rumania's Ploesti oil fields reached the area over this route as well. President Roosevelt used the Corps' South Atlantic fields when traveling to and from the Casablanca and Teheran conferences in January and November 1943. The South Atlantic ferry traffic, always heaviest in winter, peaked in March 1944 when a monthly total of 1,675 Army tactical planes passed eastward through Natal.

The Corps of Engineers' little-heralded Atlantic air base construction work during World War II helped secure the

western hemisphere from attack. Protecting islands and transoceanic routes of vital importance to the security of the nation, the bases facilitated the shipment of planes and air cargo to Europe, Asia, and Africa and provided support for antisubmarine patrols in the Atlantic. Although the 16 February 1942 German U-boat attack on oil refineries at Aruba and the brief establishment of German weather-data stations in isolated locations in Greenland and Labrador represented the only Axis incursions from the Atlantic onto the hemisphere's lands, heavy German submarine activity made the defense of the area imperative for the United States. Those attacks caused the loss of 270 ships in the Caribbean area in 1942, sending 1.25 million tons of cargo to the bottom. While the Navy conducted most of the antisubmarine campaign, Army planes also chalked up kills from new bases in Puerto Rico and Ascension Island.

Beyond their immediate value, moreover, the Atlantic bases initiated the expansion of American defense installations beyond the United States and its territories. The concept of building more advanced bases for the extension of American power overseas in an age in which air power gained new importance grew from the Atlantic bases of the early 1940s to a network of American installations in foreign territories around the globe. The Corps' valuable work in creating these wartime defensive bases led it to be called upon again after the war for this important construction assignment.

Sources for Further Reading

Stetson Conn, Rose Engelman, and Byron Fairchild's *Guarding the United States and Its Outposts* (Washington, 1964) surveys the wartime development of U.S. Army bases and garrisons in the western hemisphere.

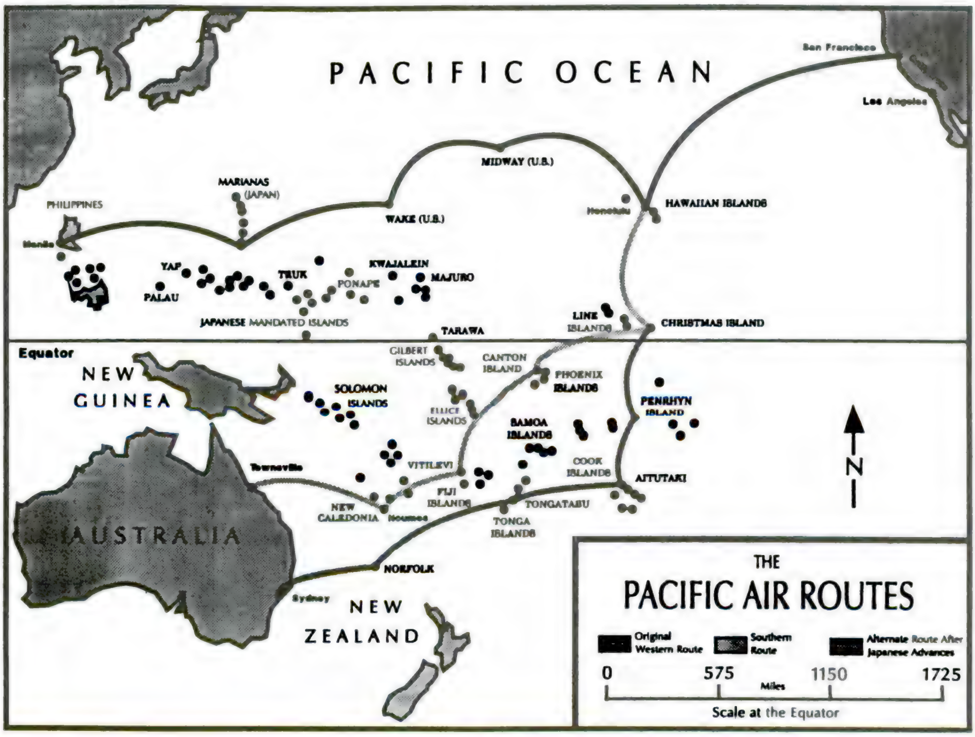
A second book by Conn and Fairchild, *The Framework of Hemisphere Defense* (Washington, 1960), examines the diplomatic and strategic underpinnings of that base development and devotes greater attention to Brazil.

An account of the wartime air ferry and transport operations which those bases facilitated may be found in Volume 1, *Plans and Early Operations* (Chicago, 1948) and Volume 7, *Services Around the World* (Chicago, 1958) of W. F. Craven and J. L. Cate, *The Army Air Forces in World War II.*

Air Ferry Routes Across the South Pacific

by Donald T. Fitzgerald

As the Japanese threat in the Far East increased in 1940, General Douglas MacArthur planned that in the event of war the Air Corps would play a major role in defending the Philippines. He also felt, as many others did, that the Japanese would not launch any attacks until the end of the 1942 monsoon season. The ensuing months would provide enough time for the Air Corps to ferry additional B-17 Flying Fortresses from the United States to the Philippines. The bombers would fly the route from California to the Territory of Hawaii, the islands of Midway, Wake, and Guam, thence to Clark Field on Luzon. However, this western route, which passed close to Japan's mandated islands, became more vulnerable as tension grew between the United States and Japan.



Pacific Air Routes

To provide a safer air ferry route, the Army Corps of Engineers Honolulu District created a new southern route to the Philippines. Airfields were built on islands and atolls stretching from Hawaii southward through the Line and Phoenix Islands, Fiji, New Caledonia, Australia, and on to the Philippines.

The Japanese, however, did not wait for the monsoon season to pass. After their air attack on Pearl Harbor, Japanese ground forces quickly occupied the Philippines and began advancing through the Southwest Pacific threatening the newly constructed southern air ferry route. To counter this threat, the engineers constructed an easterly alternate route farther removed from Japanese advances.

While developing this network of island airfields, the Pacific Ocean Engineers improvised unique logistics and engineering procedures, created specialized airfield construction units, and developed new methods of runway construction. Begun as part of America's prewar preparations, the air ferry route project became a vital element in the Southwest Pacific offensive wartime strategy.

This strategy, stated in the nation's 1924 War Plan Orange, assumed that in the event of war in the Pacific the United States would fight Japan alone; would wage primarily a naval war; and would conduct an offensive campaign to seize Japan's mandated islands, reinforce the Philippines, and finally attack Japan itself.

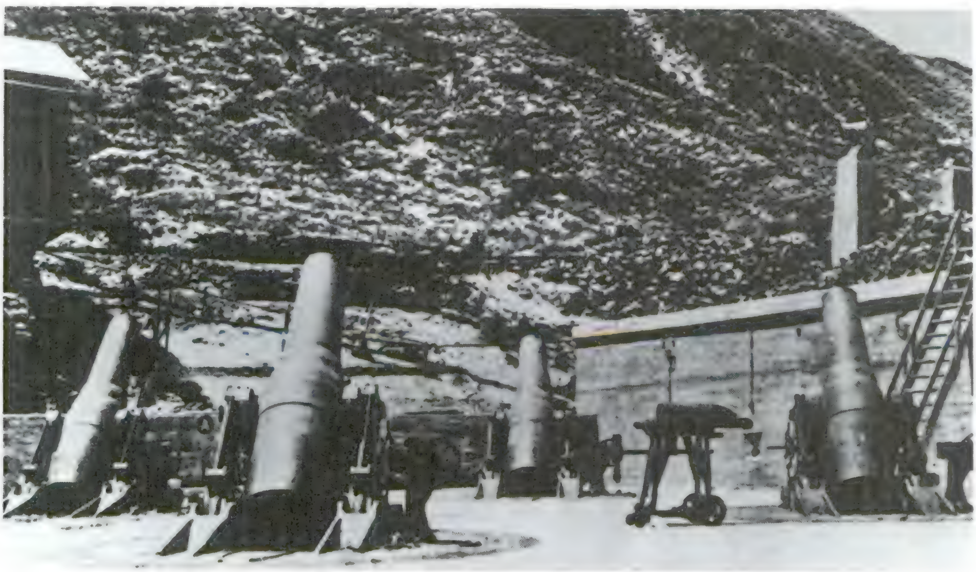
After the 1938 Munich Conference, and in view of Japan's increased military strength and America's military weakness, War Plan Orange was replaced by a series of Rainbow War Plans. One of these scenarios assumed that Japan would become allied with Germany and Italy and, after a prolonged period of strained relations, would attack the United States without warning.

This Rainbow Plan also assumed that Japanese forces would probably raid the U.S. territories in the Pacific and the West Coast. To counter this probability, the Rainbow Plan called for building up the defenses of Alaska, the Panama Canal, and Hawaii, called the "Defense Triangle" by military planners. Despite this military plan to increase the nation's defenses, Congress in 1940 reflected the public's lack of alarm by cutting to $4 million the War Department's request of

$18 million for the Defense Triangle, eliminating Alaska's proposed allotment completely and cutting the amount proposed for Hawaii in half. After France surrendered, however, Congress rushed to strengthen America's defenses.

When Major General Walter C. Short assumed command of the Hawaiian Department in February 1941, he continued this renewed emphasis on constructing Hawaiian defenses. To accomplish this, Short was able to call upon two engineer organizations: the Hawaiian Department's 3d Engineer Combat Regiment stationed at Schofield Barracks on Oahu's central plain; and the Corps of Engineers Honolulu Engineer District (HED), which had been established in 1905.

The first Army engineers in Hawaii, however, were the 2d U.S. Volunteers, who arrived in June 1898, two months after the United States declared war on Spain. The following year, their commander, Major W. C. Langfitt, drew up the Hawaiian defense plan. In 1899 Congress appropriated funds for the engineers' first construction project, dredging the entrance to Pearl Harbor. The heavy guns called for in Langfitt's coastal defense plan were not installed, however, until after the turn of the century.



Battery Harlow, Fort Ruger on the north side of Diamond Head, Hawaii. The battery of 12-inch mortars, completed in 1910, was the first modern coastal defense battery constructed to protect Hawaii from invading fleets.

Designed with the time-honored formula of bombarding approaching enemy warships and defending shorelines against invading armies, Hawaii's defenses consisted of 12-inch and 14-inch gun batteries, large mortars, and electrically mined harbor entrances protected by smaller gun emplacements.

In the 1930s, the concept of defending against air attack entered the nation's defense formula. Skyward pointing listening devices and antiaircraft gun emplacements were added to Hawaii's defenses. Then, with the development of the technology of radio detecting and ranging (RADAR), the engineers also began constructing a system of aircraft warning stations.

To accelerate the modernization of the nation's defense system and help it recover from the Great Depression, New Deal funds and labor were often transferred from public works to military construction projects such as gun emplacements, access roads, and ammunition storage facilities.

By late 1939, serious preparations for the possibility of another war in the Pacific were in full swing in Hawaii.

Fort Ruger's 16-inch guns stand ready to protect Hawaii against an enemy that never returned after striking Pearl Harbor.

On 15 July 1940, when Major Theodore Wyman, Jr., assumed command of HED, he continued those plans. In addition to assuming the standard district engineer's duties, however, he

also became works projects administrator in charge of Works Progress Administration (WPA) affairs in the Territory of Hawaii, and deputy contracting officer for the Civil Aeronautics Authority (CAA), which was developing territorial airports.

Wyman kept working on Hawaiian defense construction projects with their continued orientation towards air warfare. The Honolulu district engineer supervised the dredging of Keehi Lagoon to create seaplane runway areas (the dredged material from the lagoon was used to build John Rogers Municipal Airport), and improving civil airfields on Oahu and the outer islands. Wyman also started facilities to store 250,000 gallons of 100-octane aviation gasoline, continued constructing a series of aircraft warning stations on all the islands, and installed additional coastal defense guns and facilities.

The method of constructing Hawaii's military airfields and civilian fields with military application vividly illustrated the fragmented approach to national defense efforts which

U.S. Army fighters, pursuit planes, and bombers line up at Luke Field, Ford Island, Pearl Harbor, 1924. By this time, aviation technology, which extended Hawaiian defenses hundreds of miles seaward, was replacing the coastal defense gun system.

existed in 1940. At that time, the Quartermaster Corps constructed all Air Corps stations including their runways and facilities. To construct an air station, the Quartermaster

called upon the Corps of Engineers to do the initial survey, and called on the officer in charge of the Air Corps Building and Grounds Division to approve each design. The CAA, in building its airfields, called on the Department of the Interior for its survey work. Airfields were constructed either by troop labor, civilian labor contracted by the Quartermaster, or by workers from the WPA. Funds for airfield construction came either from the Army Air Corps, special defense legislation, or, as America became more concerned about the deteriorating situation in Europe, from the WPA itself.

In November 1940, a major change occurred in the Corps of Engineers which improved this system, and also introduced the HED to an entirely new role. During the Great Depression, the Corps of Engineers had built many large civil works projects under Franklin Roosevelt's New Deal programs. These included reservoirs, dams, hydropower facilities, and other civil works projects. As war clouds gathered, however, Roosevelt and Congress began shifting funds from civil works to military construction. As funds for civil works projects diminished, the Corps faced a declining work load and an uncertain future. To correct this situation, Army officers who were engineers exerted influence within the Army and on members of Congress to have Air Corps station construction transferred from the Quartermaster Corps to the Corps of Engineers. Their efforts were strongly supported by newly appointed Army Chief of Staff General George C. Marshall.

The campaign met partial success when, on 9 September 1940, President Franklin D. Roosevelt signed legislation authorizing the Adjutant General to transfer responsibility from the Quartermaster Corps to the Corps of Engineers for "all work pertaining to all construction at Air Corps Stations (Panama excepted), including that now in progress." The path was now open for the Honolulu district engineer to build military airfields. The engineers did not have to wait long for that opportunity.

In October 1941, the War Department directed General Short to construct a new southern route of Pacific island airfields which would allow B-17s to fly to the Philippines avoiding Japan's mandated islands. Assigned the job by Short, District Engineer Wyman called into his office DeWitt Clinton Wolfe, an engineer with the St. Louis engineering

firm of Sverdrup and Parcel. Wyman pulled down his window shades and explained the secret air route project to Wolfe. He asked Sverdrup and Parcel to survey the proposed route, select the best islands on which to site runways, and do whatever was necessary to "see to it that they're built." Wolfe relayed the request to company president Jack Sverdrup who turned the job down! Instead of taking no for an answer, Wyman asked the Chief of Engineers, Lieutenant General Eugene Reybold, to convince Sverdrup to take on the project.

Wyman's strong desire to have Sverdrup do the ferry route survey was based on a long professional relationship between these two engineers. Sverdrup, who in 1927 had formed his engineering firm with his former University of Minnesota professor John Ira Parcel, had signed his first contract with the Corps in 1933. He was hired to do work connected with the Fort Peck hydropower project by the Kansas City district engineer, a feisty young major named Theodore Wyman, Jr. Sverdrup's firm then went on to provide bridge plans for the Corps tidal-range project at Passamaquoddy Bay, Maine in 1935 and plans for three bridges to be constructed over the Panama Canal.

That same year Wyman was transferred to the Los Angeles District, where he asked Sverdrup to submit a bid on the Los Angeles flood control plan. Complying with Wyman's request, Sverdrup's bid was lower than several competing companies, gaining him a contract. Sverdrup did the design work in St. Louis while Wolfe supervised the flood control work from a newly established Los Angeles office.

When Wyman transferred to the Honolulu District Office in 1940, he asked Wolfe to sail to Honolulu. Upon arrival, Wyman briefed him on several small military construction projects that were available. Despite Wyman's assertion that there probably would be more work in the future, Wolfe turned down the projects and returned to Los Angeles. Unbeknownst to him, however, Sverdrup had previously committed the firm to design some bomb shelters in Hawaii. When he discovered this, Wolfe turned around, went back to Honolulu, and supervised the bomb shelter project. It was then that Wyman called him into his office, briefed him on the secret air route project, and finally asked General Reybold to urge Sverdrup to take the job.

Reybold was able to convince Sverdrup to accept the air route project. After traveling by train from St. Louis to San Francisco, Sverdrup flew Pan American Airways' famed China Clipper to Honolulu. He then began the project which reestablished his association with Wyman, surveying and building airfields for B-17 flights across the South Pacific.

Aircraft flights across the South Pacific, however, were not new. In 1928 Australian aviator Charles Kingsford Smith and his crew had flown the wheeled tri-motor *Southern Cross* from San Francisco to Sydney by way of Hawaii, Fiji, and Brisbane. In addition, Pan American Airways flying boats had been providing regular passenger service from the United States to the Philippines since 1936. Pan Am had also constructed seaplane operating facilities in the Phoenix Islands and New Caledonia to service its flights to Australia. Although aviation facilities were not new to the South Pacific, the air route which the engineers were about to build was a more ambitious system than anything in existence.

General Short ordered Wyman to construct ten primary and five alternate airfields, each to have at least one 5,000-foot runway capable of handling heavy bombers. To complete the project, General Short was allocated $5 million from the appropriation entitled "Defense Aid, Aircraft and Aeronautical Material (Allotment to War) 1941–1943." The War Department directive labeled the project so urgent that its completion "must be thought of in terms of weeks not years." The first runway was to be completed by 15 January 1942, in about 13 weeks.

An early B-17E lands at Eastern Island, Midway on its way to the Philippines. The proximity of Midway, Wake, and Guam to the Japanese mandated islands prompted the War Department to build the South Pacific Air Route island bases. (Smithsonian)

The ferry route was to consist of a series of runways which would link Hawaii, the Line Islands, the Phoenix Islands, Fiji, New Caledonia, and Australia, with the Philippines. Since the route paralleled the Pan American flying boat route, Pan Am base facilities such as communications stations could be used when possible. Although the airfields were primarily designed for bombers, they were also seen as a way to ferry fighter aircraft to Australia. The fighters would be assembled in Hawaii, or shipped there on aircraft carriers or as deck-load on cargo ships. The initial mission, however, was to provide a safe ferry route for B-17s.

The question of which field should be built first was settled when Wyman was told that although Canton was given priority over Christmas, both islands "should be made usable at the earliest possible date." The United States and Great Britain jointly claimed the two islands. Christmas Island, about 1,400 miles south of Hawaii, was 10 feet above sea level, 35 miles long and 20 miles wide, and the largest coral island in the Pacific. Its once numerous coconut plantations had been abandoned after the collapse of the copra market, and the island was now populated by two settlements of returned Polynesians and a British resident commissioner. To gain information on Christmas Island, Wyman sent Air Corps Major Roger M. Romey and Engineer Captain Stanford MacCasland on a reconnaissance trip by Navy seaplane. At the same time an engineer survey party, including Major B. L. Robinson, departed for the island aboard a Navy destroyer. After surveys indicated that runway construction was feasible, work started about 15 October 1941.

Canton, about 1,000 miles southwest of Christmas, consisted of a narrow strip of coral enclosing a pear-shaped lagoon measuring 8 by 4 miles. Wyman and his staff had some knowledge of Canton from the CAA which had shared plans it had prepared to construct an airfield on the island. To confirm the suitability of the island for runway construction, an engineer from the Honolulu District flew there by Pan Am Clipper on 21 October. With the sites selected, the work could now get under way.

But as soon as the project began, the district engineer faced problems in almost every possible area including labor, supplies, communications, and building equipment. The first

question Wyman faced was where he would obtain workers. When the Corps of Engineers began building Air Corps stations in the United States, it developed engineer aviation units specially trained to construct airfields. The 28th Engineer Aviation Regiment worked on Annette Field on the Alaskan panhandle in July 1940 at the insistence of Lieutenant General John L. DeWitt, commander of Alaskan defenses. When the United States acquired British bases in the destroyer-base agreement the following month, General Marshall assigned the construction of U.S. air bases to the Corps of Engineers. The Hawaiian Department received its first contingent of aviation construction specialists in April 1941, when the 804th Aviation Company arrived from the United States.

Short and Wyman agreed that the work on Christmas would be done mainly by these military engineers, assisted by some civilians. On Canton, however, they decided that labor would be supplied by Hawaiian Constructors, a company formed by three contractors from Nebraska and Nevada. Because most skilled workers were finding jobs in West Coast defense plants, Hawaiian Constructors was having a hard time finding qualified construction men for the ferry route project. Wyman's decision to rely heavily on civilian workers was soon to present him with untold headaches.

Wyman's next challenge was how to obtain and deliver supplies. The Navy supply ship USS *Antares* was to transport officers, troops, and civilian engineers and construction men to the two islands. (It was this same ship, returning from its second supply trip, that discovered a Japanese midget submarine as it attempted to enter Pearl Harbor early on the Sunday morning of the Japanese air attack.) Canton's problems started with the first supply run of the *Antares*. The ship departed Honolulu on 3 November towing four barges which carried the area engineer, Captain C. D. Baker, and about 200 troops, civilian workers, and their equipment. Eleven days later, the ship arrived off Canton with a quartermaster barge and a derrick barge; the two other barges had sunk, taking most of their equipment to the bottom. The construction crew that arrived on the island a week later was not an impressive looking group, but it was the best that Hawaiian Constructors could provide.

The Army–Navy Munitions Board had assigned top priority to the ferry route's material requirements. However, construction materials often lay piled up on San Francisco docks due to a shortage of ships. Additionally, as construction activities increased, maintaining communications between Honolulu and the islands became more and more difficult. Cable, wireless, and Pan American Airways communications facilities soon became overloaded. In order to solve these problems in logistics and communications, District Engineer Wyman chartered the former interisland steamship SS *Haleakala*. The ship delivered supplies throughout the project, and its radios maintained communications between the construction sites.

The problem of construction equipment shortages led the engineers into the field of diplomacy. From the beginning of the project, heavy construction equipment was in short supply. Before any civilian equipment arrived from the United States, the Hawaiian Department headquarters loaned Wyman some that belonged to the 804th Engineer Aviation Battalion (formerly company). General Short warned the Honolulu engineers, however, that he expected that the airfield project would probably wear out the equipment—a not so veiled hint that he expected the Honolulu District to use project funds to replace the worn-out equipment with new.

This solved the immediate need for equipment on Christmas and Canton islands. On Fiji and New Caledonia, however, only the foreign national or colonial governmental agencies constructed public works, hence only they owned heavy construction equipment. Civilian contractors, who were limited to the building trades, had none. Therefore, to obtain equipment, the Army engineers had to conduct diplomatic negotiations with the foreign agencies. Fortunately, the colonial powers and local governments were very cooperative. The Free French provided personnel and some equipment for work at Tontouta and Plaines des Gaiacs on New Caledonia. New Zealand provided all the labor and most of the equipment for work at Nandi in the Fiji Islands.

The air ferry route, however, was more than a well-coordinated engineering project in the South Pacific. It was the arrival of bulldozers and steamrollers into simple cultures centered around lagoons, fish lines, and nature. It was the

machine entering the Polynesian garden. But for Army engineers it was exciting and creative engineering, administrative and logistic innovation, and a thrilling personal challenge.

It was also an extension into the Pacific Ocean area of New Deal engineering whose energy and innovation were being transferred from civil works to military projects. In the ferry route project, this innovation even created the very materials with which runways were constructed.

In the late 1930s, most Air Corps airplanes operated off turf airfields. Even the B-17s flying to the Philippines landed on Clark Field's turf runways. Many U.S. airports, however, were beginning to build runways with asphalt. When the Corps of Engineers took over building Air Force stations, road building methods were used to build aircraft runways, parking areas, and taxiways. Layers of crushed rock were coated with tar or asphalt called tarmac or macadam, after its early 19th century Scottish inventor, John L. McAdam. Such surfaces, however, soon proved too weak to support the larger bombers which were being developed, such as the XB-19. To support such heavier aircraft, engineers began building runways of cement which pilots greatly preferred for their strength, smoothness, and all-weather capabilities.

When Army engineer aviation units started building runways on Pacific atolls and islands, they had neither asphalt nor cement. To solve this problem the engineers on Canton and Christmas islands soon developed coral, a construction material previously known to few Americans. Used for construction in some tropical areas, little was known elsewhere about coral or its use as a building material. Made up of skeletons of minute spherical marine animals, coral was chemically similar to limestone. Army engineers found that if it was crushed, rolled, and watered with either fresh or salt water, it became hard enough to use for roads and runways. If allowed to become dry, however, it rutted, powdered, and blew away. To prevent this problem the crushed coral was topped with tar, later with asphalt, and sometimes with a mixture of water and molasses. Coral runways, which were soon being constructed throughout the Pacific, had their origins in the prewar HED ferry route project.

Such improvisation produced steady progress. In the hectic months of November and early December 1941, Wyman's

engineers worked intensely to complete the route by the approaching deadline. The Japanese attack on 7 December not only forced the engineers to redouble their efforts, it also forced them to reorganize the entire air route.

The Japanese advance moved swiftly and cut deeply. The same day that they attacked Pearl Harbor, they launched assaults on the Philippines, Guam, Midway, and against British forces in Hong Kong and on the Malay Peninsula. The B-17s at Clark Field were destroyed before they could get into the air. Hope of defending the Philippines collapsed as MacArthur led his forces into the labyrinth of the Corregidor fortress. With the Philippines lost, the air route now became a lifeline to Australia, and the race was on to deliver aircraft to help in its defense.

As emergency crews battled fires at Hickham Field and Navy salvage divers searched the murky waters of Pearl Harbor, the 804th Engineers and civilian workers were clearing and grading runways on Christmas and Canton islands. Natives on Fiji were lengthening runways while the New Zealand government was providing a steady flow of equipment and material. On New Caledonia, aided by the Free French, Lieutenant Richard P. Saeur was making headway on the airfields at the Plaines des Gaiacs and Tontouta. Progress was being made toward the original deadline of 15 January, which was now more imperative than ever.

But in addition to an approaching deadline, there was an approaching enemy. The Japanese invasion of Tarawa in the Gilberts and Guadalcanal in the Solomon group threatened the route, especially the airfield on Canton. As the enemy continued to advance, General Short decided to evacuate the civilian workers from Canton and move them to New Caledonia to complete that field as quickly as possible.

More than 200 Canton workers climbed onto a barge, set up canvas shelters from the sun, and began the slow trip under tow toward American Samoa. While en route to the American possession, food and water ran short, sea sickness was widespread, and sanitary conditions were deplorable. An engineer recorded that the misery of the journey was "something each of them will never forget as long as they live." When the sick and weary workers stopped off at Samoa,

they were dismayed by the U.S. Naval Governor's order to remain on the anchored barge under quarantine. After baking in the sun for three days, the workers were struck by an epidemic of amoebic dysentery, causing the governor to finally allow them ashore to receive medical treatment. Once they regained their health, the workers continued their voyage to New Caledonia.

When the civilians departed Canton, Captain Baker and about 130 troops had remained to complete the runways. They were also prepared to defend the island with the arms General Short had sent: two 75-mm. cannon, 800 rounds of ammunition, a dozen machine guns, and a sergeant to train the engineers to fire them. Although the work continued, living conditions were deplorable and morale was low.

Unlike Canton, Christmas Island was not directly threatened by the Japanese advance. Yet events transpired there which led the civilian workers to near rebellion. Friction had developed between the Honolulu engineer officer in charge, Major John E. Shield, the Hawaiian Department military engineers, and the Hawaiian Constructors civilian workers. Dissatisfactions arising from food and water shortages were compounded when Major Shield began countermanding orders of the civilian supervisor. Less than an efficient group to start with, the workers became a confused and disorganized gang. Shield also alienated the 804th Engineers by not cooperating with them.

Shield, however, was not the only one causing friction. A military engineer officer told some of the civilian workmen that they would all end up in front of a Japanese firing squad, causing them to demand return passage to Honolulu. To quell the clamor, Shield declared martial law, enforced a seven-day work week, and prohibited anyone from leaving the island. The situation was not helped by the daily English language broadcasts from Germany of British propagandist Lord Haw Haw (William Joyce). Despite the secret nature of the air route project, he knew about the airfield being constructed on Fiji, and asked the engineers to hurry "so that the Japanese would have a nice place to land." Morale on Christmas was extremely low.

Meanwhile, work on the New Caledonia airfields at Plaines des Gaiacs and Tontouta progressed rapidly,

especially after the civilian workers arrived from Canton. In addition to their engineering duties there, Saeur and MacCasland assumed a series of unique additional assignments. After Pan Am evacuated its employees at the outbreak of hostilities, Saeur and MacCasland successfully operated the seaplane base for military use. Then, when an outbreak of bubonic plague prevented the Sverdrup and Parcel firm from bringing in civilian engineers and draftsmen from the United States, Saeur and MacCasland took over the work of architect–engineers. Perhaps their most unique role, however, involved international negotiations. Rear Admiral Thierry d'Argenlieu, the new Free French high commissioner, would only negotiate with the Army officers. With full cooperation from the New Caledonian and French authorities, progress was steady.

On 28 December 1941, 18 days after the Japanese invaded the Philippines, Colonel Wyman announced that the air ferry route was capable of handling Air Corps bombers. Between 3 and 12 January 1942, a flight of three B-17s completed the trip to Townsville, Australia, using airfields completed on Canton, Nandi, and Tontouta. The pilots reported the runways to be excellent. The trouble on Christmas Island had delayed its completion, but on 21 January a flight of B-17s landed on its runway, shortening the first leg of the journey from Hawaii by nearly 700 miles.

Army engineers applied lessons they learned from constructing the South Pacific Air Route project to building airfields for U.S. forces waging the Southwest Pacific campaign, Port Moresby, New Guinea. (Smithsonian)

Although the ferry route was operating, the Japanese army had advanced rapidly; they were in the Gilberts, and by May 1942 on Tulagi in the southern Solomons. Now the security of the entire route was threatened. Earlier in the year, Wyman had anticipated the need for an alternate route —one less likely to be overrun by the Japanese. With the approval of Washington and authorization by General Short, he contracted with Sverdrup to survey islands to the east of Canton and Christmas in order to construct an alternate and safer ferry route.

Wyman was determined that when building the alternate route airfields he would profit from the experience gained on Christmas and Canton islands. He had come to the conclusion that American workmen were not "temperamentally suited" to work on isolated and confined islands without the benefit of amusements or recreation facilities. Since he could not provide either, in planning for the alternate route, he insisted that Sverdrup select islands having indigenous populations with work habits learned in agriculture or mining. In addition, unloading supplies at Christmas and Canton had been complicated by coral reefs, shoals, and rough water in unprotected anchorages. Wyman therefore ordered Sverdrup to select islands with good natural harbors or lagoons, and enough elevation to minimize damage from storm-tossed surf.

After visiting 13 islands, Sverdrup found three good sites which eventually comprised the alternate route to Australia: Penrhyn Island in the northern Cook group, Aitutaki in the middle Cook group, and Tongatapu in the Tonga group. Wyman approved Sverdrup's recommendations, and on 11 May 1942 Washington gave the go-ahead for runway construction on the alternate route. That same month Sverdrup accepted a commission as a colonel in the Army Corps of Engineers. He served as MacArthur's chief of construction throughout the Pacific campaigns, received numerous decorations including the Distinguished Service Medal and the Legion of Merit, and was a major general at the end of the war.

In the summer of 1942, the war in the Pacific was at a crucial juncture with Japanese forces threatening to sever the line of communications between the United States and Australia. By the fall of that year, however, the alternate ferry

route was providing a vital air link between the two nations. The following year, Allied forces had consolidated their strength and began their offensive drive towards the Japanese home islands and eventual victory.

The statement often made that World War II was "an engineer's war" was graphically illustrated by the air ferry route construction program. American and Japanese construction forces raced each other to complete runways which could bring victory in the next battle. Time and distance pressed on both forces. While American Army engineers were building airfields on New Caledonia, the Japanese were building airfields on Guadalcanal, only 800 miles away.

The air ferry route project was intensive, innovative, and creative. Started during America's preparation for war, the project developed management techniques, construction materials, and innovative procedures which were used successfully throughout the war. The successful Southwest Pacific campaign relied heavily on air operations conducted from island airfields built with methods developed on the Pacific engineers' air ferry route project.

Sources for Further Reading

This essay is based on a narrative on the air ferry routes project in Erwin Thompson's *Pacific Ocean Engineers: History of the U.S. Army Corps of Engineers in the Pacific, 1905–1980*.

A summary history of the Honolulu Engineer District during World War II is contained in the three volume series: *Historical Review, Corps of Engineers, United States, Covering Operations During World War II, Pacific Ocean Area*, by Lieutenant General Robert C. Richardson, Jr., Commanding General, Oahu Engineer Service, Honolulu, undated.

A brief narrative of the district's activities during World War II is found in an unpublished manuscript by Lieutenant Colonel Willard P. McCrone entitled *The Honolulu District and Pearl Harbor*, dated December 1949.

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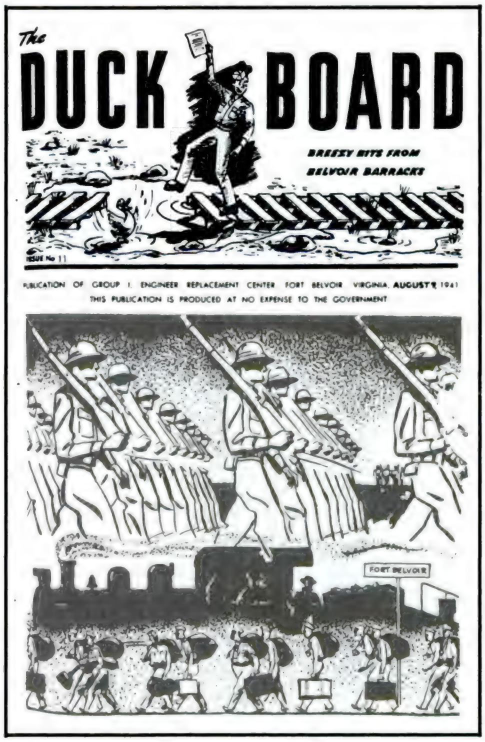
The Engineer Replacement Training Center, Fort Belvoir, Virginia

by Paul K. Walker

Beginning in mid-1940, the expansion of the Army profoundly affected the Corps of Engineers. At the end of June 1940, the number of engineers in the Regular Army stood at 810 officers and 9,973 enlisted men, an increase of 24 officers and 4,183 enlisted men since the previous June. But this growth in the enlisted ranks represented a mere trickle compared to the raging torrent which followed. The number of enlisted men, supplied largely by the draft instituted in September 1940, increased seven-fold from just under 10,000 in July 1940 to 69,079 a year later. The entire Army expanded just five and a half times.



Cover of the 9 August 1941 issue of The Duck Board, *published by Group 1, Engineer Replacement Training Center, Fort Belvoir, Virginia.*

The influx of so many men translated into a substantial requirement for additional training. The peacetime practice of training recruits in units was impractical. To help meet the need, plans were formulated in November 1940 to establish an Engineer Replacement Training Center (ERTC) at Fort Belvoir, Virginia.

The location was a natural choice. Belvoir predated World War I as a training ground for Army engineers. The War Department had acquired the Belvoir estate in 1912 as a rifle range and summer camp for engineer troops stationed at Washington Barracks in downtown Washington. During

World War I, the Army trained thousands of engineer officers and troops in basic military engineering at Belvoir before sending them overseas. The entire Engineer School relocated in 1919 to the site, known then as Camp A.A. Humphreys.

In May 1920, the War Department established a program for the Engineer School which was followed until World War II. The plan set up departments of Administration and History, Military Art, Civil Engineering (relating specifically to rivers and harbors), and Military Engineering. Initially, instruction included a basic course, an advanced course (later renamed as a company officers course), noncommissioned and enlisted specialist courses, correspondence courses, and "special courses." Also during the interwar period, the name Camp Humphreys changed successively to Fort Humphreys and finally to Fort Belvoir, as the camp evolved from a collection of temporary facilities to a permanent post.

By mid-December 1940, a cadre had formed for the ERTC with Lieutenant Colonel William M. Hoge in command. Meanwhile, barracks and other improvements were constructed at the site of the new center—a run-down farm across U.S. Route 1 from the main post. The site was selected, not only because of its proximity to Belvoir, but also because its terrain was suited to all types of training.

Preparation of the training center for the new enlistees required a pool of competent instructors. The officers comprising this group came largely from the Officers Reserve Corps, with a few from the Regular Army. The Engineer School conducted five-week officer instructor courses for the reservists. The first took place in November–December 1940. Two more sessions were completed by 3 March 1941. Upon graduation, the officers moved directly into the training center organization. Some would serve as company officers or in positions within the headquarters. Later, graduates of the Belvoir Officer Candidates School joined the training center staff.

Noncommissioned officers (NCOs) also assisted with instruction. An NCO instructors course involving 900 men taken from existing engineer organizations, and under the command of Lieutenant Colonel George W. Gillette, began 2 January and lasted until 8 March 1941. As cantonments were completed, the NCOs moved in to test them out for

the ERTC trainees. Their training schedule paralleled that planned for the selectees. When the course was over, half the officers and men went to the Belvoir center. The other half reported to a second center being organized at Fort Leonard Wood. Additional courses held included company officer activities, adjutant and administrative classes, and mess management.

Activity was intense at the Belvoir ERTC in early 1941 as the cadre organized headquarters, groups, battalions, and companies. Officers in headquarters developed training schedules and prepared training areas. They sited nearby locations for fixed and floating bridges, demolitions, field fortifications, roads, construction, obstacles, and weapons. The supply branch busily prepared for the anticipated full quota of 250 officers and 10,000 men, as heavy engineer equipment, machines, and ponton boats poured in. Thousands of workmen labored to complete the barracks, service clubs, theaters, hostess houses, post exchanges, and recreation areas that would serve each group of trainees.

The Belvoir center included the headquarters, a headquarters company, and two training groups segregated by race. The white group consisted of seven battalions with 28 companies; the "colored" group had three battalions of 12 companies. Each training company consisted of four platoons. The center headquarters had 32 officers and no enlisted men. Two officers commanded the headquarters company and utilized enlisted men in its personnel, supply, training, drafting, and transport sections. Each group had its own headquarters with six officers and 15 enlisted men. Group headquarters dealt with supply, mess, recreation, and disciplining its battalions. The groups each had their own areas and facilities. Battalion headquarters contained two officers and 11 enlisted men. Each company had 229 trainees with a cadre of five officers and 23 enlisted men.

The first group of 250 selectees arrived at the Fort Belvoir ERTC from Camp Lee, Virginia, on 17 March 1941. Landscaping, road paving, laying of sidewalks, painting barracks, and other important jobs remained to be done to complete the new center. But the job of training selectees as fillers for units being organized for war began without delay.

To prepare as fillers for new units, the selectees embarked on a 564-hour course spread over 12 weeks. The course covered some 40 subjects related to the duties and specialties of engineer soldiers. Subjects were grouped as basic and general (166 hours); weapons (84 hours); combat (48 hours); engineer (126 hours); and pioneer (92 hours). Six days of additional training remained to be distributed as needed. Full training days were scheduled Monday through Friday with a half-day on Saturday. During the course, three full days were set aside for field training.

The soldier's life was not all work. There were frequent games and athletic competition. Separate service clubs for the white and black groups provided restaurants, lounges, and libraries as gathering places away from the routine of their standard 63-man, double-deck "pagoda" style barracks. In April 1941, the selectees formed a band as well as two orchestras and held dances twice a week. Movie theaters and post exchanges were also available.

The Military Obstacle Course, known popularly as a "steeplechase for soldiers," was central to the soldier's training. The first of its kind to be used by the Army, the Belvoir course challenged trainees with a series of obstacles which required climbing, crawling, swinging, hopping, and jumping.

The 8-foot smooth wall from the Military Obstacle Course, Fort Belvoir, Virginia, 1941. The training course, first of its kind in the Army, was popularly known as the "steeplechase for soldiers."

The course started with a 2-foot hurdle and ended with 12-foot ladders and a 6-foot breastwork. The course was wide enough for several men to compete with each other.

Parts of the original course were deemed too easy, so Major Lewis Prentiss designed several new obstacles to challenge the troops. They dove down a 20-foot fireman's pole; boarded a ship by climbing up cargo netting from the rolling gunwales of a rowboat; crossed a stream by overhead horizontal ladder; and ended with a climb up a 45-degree slope. The new course was so popular that the Belvoir center sent its plans to other training centers. "Even football coaches investigated its features," according to the *Military Engineer*.

As the first group of selectees underwent training in the spring of 1941, several weaknesses in the ERTC organization became clear. One problem was a shortage of officers. In April Colonel Hoge opined that existing tables of organization provided only a bare minimum of the reserve officers needed. The organization did not account for officers needed to perform essential administrative duties such as police, fire, mess, and motor transport; nor did it account for the normal complement of officers absent for sickness, leave, or other duty.

Hoge's successor, Brigadier General Edwin H. Marks, took over on 1 May and shortly thereafter proposed a revision of the center's tables of organization. The basic problem was that too many officers and selectees had to be diverted from training to other tasks. Some platoons were receiving inadequate instruction, and trainees were missing essential training. Marks requested an increase of 85 officers and 444 enlisted cadre to correct the situation lest the training of future classes also fall short.

Brigadier General Edwin Hall Marks, Corps of Engineers, commanded Fort Belvoir, Virginia from 1941 to 1944.

The center also needed new positions to augment the headquarters' personnel, administrative, and supply sections. Additional enlisted men were required at headquarters to do classification work and operate the post office. An increase of one officer per replacement company to handle mess, supply, and administration would free company and platoon leaders for training. An increase of one corporal per platoon would provide a permanent squad leader for each of three squads.

Ten medical officers and 60 enlisted men were needed to operate infirmaries, give medical instruction, and provide medical attention in training areas and on the march. A unique requirement remained for special training battalions to handle the physically and mentally handicapped.

By the end of summer 1941, several changes had occurred. In July a special training company was created for mentally and physically impaired recruits. All motor personnel were concentrated in a new motor company, but fewer than one-fourth of the additional enlisted men requested by Marks were added to the ERTC's table of organization. The specialized training unit enabled it to retain many recruits who might otherwise have been lost because of illiteracy and mental, physical, or emotional problems.

Despite difficulties encountered in its first nine months of operation, the Belvoir ERTC and a second center opened in May 1941 at Fort Leonard Wood, Missouri, were able to meet the Army's need of fillers for newly activated units. The first shipment of 1,035 trained selectees left Belvoir for Fort Bragg, North Carolina, at the end of May. A second group entered in July. Before the end of the year, the two centers were graduating about 5,000 men per month.

Pearl Harbor changed all of this drastically. The impact was immediate. Within two weeks (December 19) the Army shortened replacement training by one-third, from 12 to 8 weeks. The War Department's preferred solution was to cut the time allotted to each course rather than whole courses. The center adopted a program developed by the Operations and Training Branch, Office of the Chief of Engineers (OCE), that primarily reduced the number of technical subjects originally included in the closing weeks of training. Now units were expected to take up the slack.

The condensed 8-week course lasted only until 15 March 1942, when the general staff ordered a gradual reversion to a 12-week cycle. The change brought more time for engineer subjects such as demolitions, bridging, road construction, and obstacles. This was fortunate. Troops were simply moving overseas too fast. In reality the training they received at the centers was all they got before they entered a combat theater.

Spring 1942 also brought a reorganization of the Army. Services of Supply (SOS), a new command, assumed control of the Corps of Engineers except in matters related to civil works. Thereafter, the Training Division of SOS assumed close supervision of all aspects of training. The goal was uniformity in order to produce men at desirable levels of proficiency. In August, SOS issued a basic military program to be used by all training centers during 163 of the 192 hours in the first four weeks. Under the new plan, instruction changed over to engineer subjects in the fifth week.

Rifle firing remained of highest importance. While at the center, every trainee was required to fire for record. Shortages of weapons and suitable firing ranges hampered both training centers. Belvoir had one 88-target range. The requirement

Engineers build an assault boat ponton bridge (10-ton capacity) with two fixed steel trestles on the shore.

that 80 percent of the trainees qualify was difficult to attain. Military courtesy, drill, and other aspects of basic training in addition to marksmanship characterized the program at all centers, but Belvoir and Leonard Wood sought to produce technically trained soldiers. For 7 of the 12 weeks of training the engineer recruits combined technical with tactical instruction. Trainees learned the elements of reconnaissance, coordination with larger groups, and building fixed and floating bridges, roads, and obstacles.

Although the initial training phase utilized scale models, practical experience in the field was at the heart of engineer training. In the floating bridge area—a 2,000-foot dredged channel that ranged to 250 feet wide—six companies could train simultaneously. Accotink Creek accommodated 4 steel bridges, 16 wooden trestle bridges, and 48 foot bridges at one time. Building 180 fixed and floating bridges in a single week was common. Bailey bridge training followed final adoption of the bridge by the Corps in February 1943.

Carrying firsthand experience forward into training, recruits also learned how to make priming charges and fire explosives. Twenty hours of roadbuilding instruction were divided into four parts. Trainees learned how to spread gravel; dig ditches; lay pipe; clear and drain fields; lay matting; mix and pour concrete; build corduroy, wire mesh, and landing mat roads; and conduct repair and maintenance. The last four-hour training segment was a night operation that might include expedient road building or repair.

Although the 12-week course had been restored, training in the first nine months of 1942 was relatively hasty and took place in an atmosphere of increasing urgency. The ERTC facilities expanded to accommodate additional recruits. Initial planning that called for 8,800 men was increased to 10,000. In June 1942, the Belvoir center graduated a peak of 4,444 trainees.

On 2 July Brigadier General Lehman W. Miller assumed command of the ERTC from General Marks. By this time the need for trained specialists in engineer units had reached emergency levels. Planners had mistakenly expected the draft to supply the Army with more than enough specialists. The Corps of Engineers, which required 727 occupational specialists per 1,000 troops, was exceeded only by the Transportation

Corps in its need for skilled and semiskilled men. Quotas for construction machinery operators were the hardest to fill. The center had to find a way to meet the crisis while continuing to produce soldiers trained in the basics.

Beginning in August, the ERTC separated arriving specialists from other recruits based on their qualification cards. The specialists then spent four weeks in basic training and one week studying technical engineering subjects before assignment to a specialists school either at Belvoir itself or in the civilian sector. One company from each of seven battalions became a specialist company.

In a program combining theory and practice, the ERTC offered basic specialist training for construction machinery operators, carpenters, truck drivers, and demolitions handlers, as well as buglers, messengers, clerks, mess sergeants, cooks, and bakers. Trainees in carpentry helped build classrooms at the center. Machine operators gained firsthand experience clearing roads, excavating pools, and preparing firing ranges.

Specialists took advanced courses at trade and service schools. Under contract, the University of Kentucky gave courses in drafting, surveying, and geodetic computing to white enlistees while the Virginia State College for Negroes trained black topographic specialists. Under similar arrangements, the Radio-Television Institute trained electricians. Caterpillar Tractor Company and R.G. LeTourneau Company trained machinery operators.

The demand for specialists dominated the engineer training program until summer 1943. Despite shortages of instructors and machinery, the Belvoir and Leonard Wood centers together were able to produce the required number of specialists. Out of 82,301 men received in the year following June 1942, the centers trained 14,409 (17.5 percent) as specialists.

Spring 1943 brought further changes. The ERTC's emphasis shifted from furnishing fillers for new units to replacing battle casualties. Trainees generally went directly into units in combat, and it was now virtually impossible to obtain additional training from their new units prior to embarkation as they had in the past.

The situation placed heavy demands on the replacement program. Lieutenant Colonel Ralph Bailey, the center's new

As part of their training at Fort Belvoir, Virginia, engineers test how well an obstacle can withstand a tank attack.

S-3, introduced new subjects to the curriculum and changed the methods of teaching to include more widespread use of training aids. Higher headquarters required that all replacements must "so far as practicable. . . be subjected during training to every sight, sound, and sensation of battle." Live ammunition, real mines, and a night bridging operation were introduced. Experience gained in combat in North Africa called for more tanks in training and for testing bridges and obstacles. Instructors also placed greater emphasis on building physical endurance.

By summer 1943, the specialist crisis was under control. The center should then have entered a relatively stable period and been able to develop a program, long hoped for, that would turn out soldiers who could fight; who had broad technical knowledge; and who, if required, could perform skilled work. Unfortunately several factors prevented that from happening.

The center instituted a new 17-week training program in August. The program was designed to produce both adequately trained specialists and nonspecialists. All spent the first six weeks in basic training. The specialists then spent eight weeks in specialist courses while the others trained in basic engineering tasks. For the last three weeks the two

military occupation specialist code) that set them apart from basic replacements from the other services. The technical knowledge received through the Belvoir training program was the distinctive characteristic of the engineer soldier.

Sources for Further Reading

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The research notes for *Troops and Equipment* in the research collections of the Office of History, U.S. Army Corps of Engineers, were indispensable.

"The Fighting Engineers," a film produced for the Department of the Army by Warner Brothers in 1942, provides an excellent visual record of the Belvoir ERTC. A videotape copy of the film is in the research collections of the Office of History, U.S. Army Corps of Engineers.

The Engineer Replacement Training Center, Fort Leonard Wood, Missouri

by Larry Roberts

Shortly before Thanksgiving 1940 two automobiles carrying constructing quartermasters (CQMs) arrived in the Ozarks. These individuals were the first echelon of a military and civilian force that would carve a new training center out of the rugged terrain of southern Missouri.

The purpose of the new post was two fold. It would serve as a divisional training center and would also be the site of an Engineer Replacement Training Center (ERTC). Although there were other division training camps across the country, Fort Leonard Wood's ERTC would initially be one of only two such activities, the other located at Fort Belvoir, Virginia.

The challenge facing those first to arrive in the area, and the thousands who would come in the following weeks, was formidable. Personnel for both the ERTC and the 6th Infantry Division would begin arriving in a matter of weeks. Engineers, planners, and construction workers had to have the new post ready in five months. Then the military trainers and administrative personnel had to prepare thousands of men for the war that was rapidly closing in on the nation.

Little prior work had been done when the CQMs arrived in November. Initially the War Department wanted to build a Seventh Corps Area Training Center near Leon, Iowa, but the Seventh Corps commander preferred the Missouri location. In the fall of 1940, the War Department learned that there were problems with the Iowa location. The water table had dropped 60 feet since 1918 and the projected cost of impounding sufficient water for the post was prohibitive. The major disadvantage of the Missouri location was its distance from the nearest railroad. The sense of urgency which permeated the War Department in 1940 prompted the decision for the Ozark cantonment. The architect–engineer firm of Alvord, Burdick, and Howson of Chicago, Illinois, was told to stop work on the Iowa site and proceed to Missouri.

Company representatives arrived in nearby Rolla, Missouri, in mid-November.

The task was to build a training center for 37,800 division soldiers and engineer recruits on a broad ridge south of the community of Waynesville. The area was broken by numerous ravines leading to the Roubidoux and Big Piney creeks, tributaries of the Gasconade River. The dominant vegetation was second-growth timber, mostly pine and oak, with some walnut, hickory, and other trees. The soil was a thin clay loam mixed with small flint stones, underlaid by both limestone and sandstone. The only substantial topsoil of agricultural value was in the numerous creek and river bottoms. The topography of the future fort proved both a blessing and a curse. The rugged landscape offered excellent training potential, especially for the engineers. However the same ground posed significant challenges for the planner and builder. The summers were hot and humid, but the winters were mild. The Ozark Mountains shielded the region from the harsh winters of the plains, and snowfall—at times abundant—melted quickly.

The population of the region was small; the nearest community had less than 500 inhabitants. Most of the people lived on small farms with rural hamlets dotting the cantonment area. These settlements, sometimes comprising only a grocery store, a filling station, and a few houses, soon disappeared. The construction of the training center dispossessed approximately 800 people.

The U.S. Forest Service had begun the process of acquiring substantial tracts of land in the region, and that proved a major consideration in selecting the Missouri site. The Corps could more easily obtain land from another government agency than from private owners. But a problem still existed. The Forest Service had purchased only untillable lands, leaving the tillable lands to the farmers. Consequently, CQMs and architect–engineers discovered that they needed a major real estate acquisition program. Planners needed land for the cantonment and training areas, and also for rights-of-way for the railroad and utility lines, construction material storage, and borrow pits for road material. Some of this ground had to be taken from farms which had been worked for generations.

Consequently an organization comprising four firms: W.A. Klinger and Sons of Sioux City, Iowa; Arthur H. Neumann Brothers, Inc, Des Moines, Iowa; Western Contracting Corporation; and C.F. Lytle Company, also of Sioux City, was established. For the purposes of the project, this organization was called the K.N.W.L. Company. Although the Lytle Company and the Western Contracting Corporation provided 90 percent of the working capital, all decisions came from an executive committee composed of one representative from each firm. Constant arbitration of issues and many disagreements between company representatives caused numerous delays. Ultimately the joint company hired one supervising engineer as the project manager.

In large part, the contractor's initial disagreements were due to the demand for speed. With troops anticipated to arrive in early January, requirements for buildings, roads, utilities,

Construction of one of the 600 barracks built at Fort Leonard Wood, Missouri, 1941.

and railroad lines competed with each other. Construction of barracks, along with associated structures, became the dominant consideration. Excavation and form work for barracks began on 11 December; workers poured the first concrete for the foundations the following day. By 3 January workmen had the first barracks ready for occupancy. Contractors constantly diverted heavy equipment needed for road

and railroad construction to the building effort. Heavy rains in December often meant that bulldozers had to be used to tow material-laden trucks through the axle-deep mud.

The first units to arrive on post found conditions slightly better than field bivouacs. Although generally completed, the buildings lacked plumbing. Soldiers had to chop firewood for stoves and used those same stoves to heat river water for shaving. Once or twice a week, units sent their men to the nearby communities of Lebanon or Rolla for showers.

Soldiers found moving around the post a challenge. Many units built wooden sidewalks to keep the soldiers from sinking into the same morass that consumed the vehicles. At road crossings, soldiers lowered wooden drawbridges to gain access across the mud streets. Once on the other side, they raised these structures to preclude their destruction by vehicles. At one point, Colonel Frank Reed, the post engineer, purchased 75 horses so that supervisory personnel could make their rounds of construction activities. One of the first engineer units to arrive at Fort Leonard Wood spent its first weeks working on the barracks, grading and draining the battalion area, and constructing service roads.

The need for serviceable roads became so great that some construction was suspended so that heavy equipment could work on the road system. Initially, engineers sought to stabilize the roads by dumping river gravel on the thoroughfares. However this material, much like washed rock, had no binding agent and the gravel slowly disappeared into the ooze. Midway in the construction effort, engineers found that local limestone deposits could produce sufficient crushed stone for the base coat. By the end of construction, the Myron–Baker Company had produced more than 78,000 cubic yards of crushed limestone for the post roads.

With this material available, workers removed the mud and gravel down to the clay hard pan and filled the void with 8 to 12 inches of the crushed limestone rock. This was an extremely time-consuming process. When building began, no street plan had been developed for the post. As a result, buildings got the best sites, leaving the poorer areas for the roads and utilities. Consequently, the production of all-weather roads, a total of more than 50 miles, took almost one year to complete.

Post engineers and contractors also had to contend with the service roads leading to the post. The major transportation route to the post was U.S. Highway 66. However, the traffic count over this route sometimes reached more than 7,000 vehicles a day. The steep grades on U.S. 66 meant that trucks took considerable time between the cantonment and the supply point at Newburg, creating traffic jams on the highway as administrative vehicles, workers' cars, and general traffic piled up behind the heavy transports. To solve this problem engineers worked on secondary access roads and on some state and country roads. In one instance it took more than 60 days to complete a service road to the post because of a lack of heavy machinery. This included building high truss bridges across the Big Piney and Mill creeks, and numerous low-level stream crossings. When completed, more than 200 vehicles used this secondary artery each day.

Construction engineers experienced some of the same problems with building the vital rail link to the Newburg station. Work on the rail connection to the Frisco railhead at Newburg began in early December, but by mid-February only one-half mile of track had been laid. Once again, lack of heavy equipment was the dominant obstacle in completing the almost 20 miles of required track. In January, a reorganization of the work staff, additional machinery and manpower, and a move to three work shifts brought dramatic results. On 7 March only 4 percent of the route had been graded; by the end of the month the contractor had completed 90 percent of the grading requirement, moving earth totalling more than 1.5 million cubic yards.

As with the construction of the installation, the rugged terrain inhibited activities. Of the almost 20 miles of track laid from the post to Newburg, there was only 1½ miles of level track. The route had 70 curves, 68 cuts and fills, and major steel truss bridges over the Big and Little Piney creeks. The first train rolled into Fort Leonard Wood on 19 April. On 8 May the first trainload of supplies arrived on the post. Within a year the post was receiving approximately 1,500 tons of supplies each day from the 20 to 25 rail cars of each train. The engineers used the rail line to provide weekend excursions for 700 to 1,000 soldiers each week.

Bringing power and water service to the post was as much a challenge as building barracks, storage buildings, or roads. The architect–engineer and CQMs decided that buying power from a local utility company was cheaper and easier than power production on post. This necessitated securing rights-of-way for transmission lines and substations, as well as their physical construction. In February, engineers completed temporary lines to a Missouri Electric Power Company substation that provided sufficient energy for construction purposes. At the same time, workers from the post and from the Rural Electrification Administration labored on 20 miles of permanent line to the Union Electric Company's substation.

Construction of the power distribution system on the post fell victim to similar problems. Location stakes for power poles disappeared as a result of building and road construction. The rain softened the earth, causing the holes for power poles to fill in before the poles could be set. Poles already set in place suffered damage from heavy equipment. In some instances completed pole line work had to be changed to permit relocation of buildings to fit topography or to provide for water and sewer construction. Engineers finally decided to suspend all work on the distribution system until other work was generally completed. This delay was offset by the rapid progress workers made without impediments from other construction. Utilizing more than 2,500 utility poles and almost 2 million feet of wire, workers finished the distribution system in mid-April. The permanent substations and power connections were not completed until June.

Bringing water and sewer service to the post was only slightly less difficult than securing electrical service. Water for the cantonment came from the Big Piney River located near the installation. From the river pumping station, engineers had to construct more than 8,000 feet of service line to the purification station in the southeast part of the cantonment area. In the course of construction, the 16-inch main broke several times because of closed valves or from the absence or failure of pressure valves. In the construction area, water lines had to take "somewhat devious routes" to certain areas due to the rough terrain. Engineers wisely decided to bury the water line 3 feet deep as a precaution against cold weather. However, the inclement weather of the winter and

spring months meant that many trenches collapsed or filled in before pipe was laid.

Generally the water lines were in place and ready for use by the time troops arrived at major areas of the post. By the end of May, workers had installed more than 62 miles of main and service water lines, placed 353 fire hydrants, and used more than 1 million bricks on 900 manholes to support the system. As with the electrical system, the water supply was actually designed for more than the authorized strength of the post. Sewer and water systems could handle 40,000 individuals at maximum loads. More than 52 miles of sewer lines drained the cantonment area into the treatment plant. Pumping stations, filtration plants, and sewage treatment facilities were the only structures designed specifically for Fort Leonard Wood. The barracks, storage, and administrative buildings all conformed to standard quartermaster specifications.

By early June, the army of engineers, construction foremen, and workers had completed almost 1,600 buildings on the new post and the associated utilities. They used more than 75 million board feet of lumber, 80,000 cubic yards of concrete, and almost 4,000 pieces of machinery. Workers completed more than 5.3 million square feet of building space at a cost to the government of slightly more than $37 million. The Seventh Corps Area Training Center at Fort Leonard Wood was ready for its wartime mission.

Physical conditioning at Fort Leonard Wood, Missouri.

Even while construction workers were raising barracks, administration, and other buildings, units began arriving at Fort Leonard Wood. The first units belonged to the 6th Infantry Division. This division, as well as the four which followed it, used the post to complete much of the needed unit training prior to deployment overseas. It was not until mid-spring that elements of the ERTC moved to the Missouri training post.

The prewar training plan for engineers included two engineer replacement centers that would provide basic and engineer-related training for Selective Service inductees. The Army logically placed one of these centers at the Engineer School at Fort Belvoir, Virginia. It placed the other at Fort Leonard Wood. From December 1940 to April 1941, a provisional headquarters for the Leonard Wood center began to take shape at Fort Belvoir. A number of the officers and noncommissioned officers (NCOs) scheduled to conduct and supervise training at Leonard Wood trained in one of several instructor training courses at Belvoir. The idea was to have officers and NCOs observe and, if possible, teach some of the classes in Virginia before establishing the ERTC in Missouri. This would provide some uniformity of training between the two centers.

In March, the Army activated Headquarters, Engineer Replacement Training Center, Fort Leonard Wood (Provisional) at Fort Belvoir. At the same time, Companies A–D of nine engineer training (ET) battalions also came into existence. On 2 April, the Army activated the headquarters and headquarters detachments of the 6th and 7th Engineer Training Groups at Belvoir. In the segregated environment of the 1940s, the 6th trained white soldiers and the 7th instructed black soldiers. In the latter days of April, these units gathered their personnel and as much of the training literature from the Engineer School as they could carry, and went to Missouri. Of the initial complement of 163 officers, only 32 came from Regular Army units. Some 128 reserve officers came from the Engineer School where they had taken instructors courses. The remaining men came from either the adjutant general or the supply schools. Of the original 386 enlisted men, all but 4 came from the NCO School at Belvoir. Later an additional 127 officers and 1,032 enlisted men joined

obstacles, demolitions, and field fortifications. The last phase of the training dealt with the basic tactics of the infantry. Soldiers learned scouting and patrolling; infantry squad, platoon, and company tactics; and finally night operations.

On 22 April 1941 Headquarters, ERTC, Fort Leonard Wood, opened its doors for business. The following day Brigadier General Ulysses Grant III assumed command of the ERTC. Three weeks later the first group of white selectees —198 new soldiers—arrived from the reception center at Fort Leavenworth. On 21 May the first contingent of black soldiers came to the ERTC. The 26th Engineer Training Battalion, 6th Engineer Training Group, began the first class of instruction on 26 May. The training capacity of the ERTC was 10,000, and by the end of July, the center was operating at capacity.

The ERTC cadre and selectees had to overcome a number of obstacles in the first year of training. The first of these was due to construction. Originally, the cadre was to arrive on post in mid-February, but construction delays, due mostly to weather, caused the ERTC to postpone its movement from Belvoir until April. The rail line to the post was so close to

Field expedient raft training with a 37-mm. gun, Big Piney River, Fort Leonard Wood, Missouri, 1941.

the firing range that firing had to be suspended every time a train arrived. A general shortage of ranges meant that training schedules had to revolve around a unit's access to the ranges for weapons training. Classroom facilities were insufficient. The lack of company day rooms forced company trainers to hold a number of classes in the barracks, amidst the beds and footlockers. The battalion recreational halls were often the only structures available for showing films to the battalion.

Training materials were another problem. Training manuals and instructional texts, available in quantity at the beginning, were often verbose and contained outdated information. Updated texts were almost impossible to obtain for the instructors. Training aids were also inadequate. The ERTC had few resources for making its own support material, and higher headquarters, including the Seventh Corps Area Command, often failed to provide usable items. At one point, higher headquarters actually forbade local purchase or production of training aids such as posters and commercial fireworks. Like many of the manuals, training films were often obsolete.

Another problem was the quantity and quality of cadre. Few of the initial training instructors had extensive experience in the conduct or management of training. Most of the reserve officers had limited service time, if any. A number of NCOs lacked basic instructor training although they had been trained on special skills. Shortages in cadre, especially among enlisted personnel, were often met by retaining high quality selectees who had completed their training. These individuals received only a few weeks of supplemental training and practice before assuming their teaching responsibilities.

The last major problem to affect the ERTC, not only in its initial year but also in following years, was the erratic arrival of selectees for training. In some instances more selectees arrived than projected. Barracks designed for 64 men now housed 95 soldiers. In some instances tent cities housed the overflow. A flood of new trainees sometimes meant curtailing training for those in cycle in order to make space and training areas available. Because trainees were segregated by race, barracks space in the black training battalions could not be used to house white troops and vice versa.

The race issue made the ERTC leadership apprehensive about facilities off post. There were few blacks living in the surrounding communities. The nearest cities with sizable black populations were St. Louis and Kansas City. Some feared that local communities would not welcome black soldiers, and with comparatively few recreational facilities on post, black soldiers would have little opportunity for relaxation. However, local communities did respond to the needs of the black trainees. Several towns built black USOs on a par with the facilities for white soldiers. Recreation officers arranged excursion trips to St. Louis and Kansas City for black soldiers. To the extent possible, black recreation facilities on post were developed to the same extent as those for white personnel. As a result of these efforts, comparatively few racial problems occurred at the ERTC.

Even before the end of the first year of operation, the ERTC began making adjustments to its training program. One of the first involved soldiers who did not meet basic entrance standards. In September 1941, the center established an elementary school for those selectees who lacked a basic education. In time the post expanded this special training to four basic groups. The first included those who could not read or write, a second group consisted of individuals who scored low on the basic aptitude tests, a third included individuals considered mentally unstable, and the final category encompassed those who had physical limitations.

The program for these individuals involved both psychological and physical evaluation, and training geared to their special needs. The purpose was to bring these soldiers to the point where they could return to the regular training cycle. The numbers involved in this program were never significant. At one point, 80 soldiers were part of this program. Training for this group involved four two-week periods in areas such as military courtesy, guard duty, first aid, and care and maintenance of equipment. Other than those instances where mental or physical conditions required reclassification or separation, the program was generally successful. Few selectees had to complete the entire eight-week program before returning to standard training units. Much of this success was attributed to the high quality of officers

and NCOs involved in the effort. Many of them had extensive civilian experience in adult training and education.

Yet another adjustment to the ERTC training program involved specialist training. The engineer branch required an exceptionally large number of specialists. These individuals ranged from carpenters to construction foremen. There were a total of 91 different types of specialists required by the engineers. By comparison, the infantry required only 40 different specializations. In the average engineer unit, 60 percent of the troops were specialists, compared to less than 50 percent for most combat arms units.

The initial plan for the Leonard Wood ERTC called for minimal specialist training. General Grant, the first commander, limited specialist training to those areas of immediate need to the center such as cooks, drivers, and administrative personnel. It was believed that Fort Belvoir, particularly the Engineer School and the ERTC, would handle all engineer specialist training. However, it was soon recognized that Belvoir could not produce the numbers of specialists needed for the expanding U.S. Army. Consequently the Army established some engineer specialist training at Fort Leonard Wood.

The ERTC responded to this additional training requirement by forming specialist training units—at one point placing them in a special training group. Instructors were often excess personnel, or those whose duties allowed additional work. In some instances trainees with extensive civilian experience were retained as instructors after their training was completed. Facilities were never adequate for this training, and instructors for specialist training often had to scrounge for unoccupied space on an ad hoc basis.

The shifting demands for engineer units often brought abrupt shifts in specialist training. In one instance the ERTC had been alerted to prepare specialist training for a general service regiment. However, just prior to the completion of basic training for these soldiers, higher headquarters directed the conversion of the unit to a number of dump truck companies. This placed an additional training load of 1,000 soldiers on a motor vehicle operators course already having difficulty meeting replacement requirements.

Yet another added requirement, one not identified in the original mission of the ERTC, was officer training. Before the war, the ideal assignment for a young engineer officer was two years with troops, one year of graduate civil schooling, nine months at the Engineer School, and two years of rivers and harbors duty. The rapid expansion of the Army made this standard impossible. The development of officer candidate schools (OCS) and refresher training courses was an attempt to train as many engineer officers as possible in the shortest amount of time. As with specialist training, the initial plan called for all of this instruction to be conducted at the Engineer School at Fort Belvoir.

In the early days of the ERTC, many of the officer cadre reporting to Fort Leonard Wood had graduated from the Belvoir programs. However, as the Army expanded, more and more officers arrived without benefit of either the regular engineer officers course or even the refresher training. In January 1942 the Chief of Engineers directed the development of special officers training courses at the two ERTCs. The initial program at Fort Leonard Wood involved a six-week course: four weeks of refresher training and two weeks with a training company. However, the demand for officers was so great that, by the fourth class, this program had been reduced to two weeks. Ultimately the school established and maintained a four-week program until an overall shortage of students resulted in the end of the program in 1943. The prewar perception of the qualified professional engineer officer so dominated officer training that completion requirements were extremely rigid. Consequently, noncompletion rates for some classes ran as high as 50 percent.

The ERTC also conducted classes for those individuals selected for the engineer OCS. Again the requirements for successful OCS completion were so stringent that many individuals lacking basic engineering skills failed to complete the course. The OCS preparatory classes attempted to improve completion rates. In addition, the ERTC conducted special classes for officers assigned to railway construction and operation battalions. These individuals, generally commissioned directly from civilian life, needed a short but general orientation to their military duties.

The officer training programs suffered from the same problems as other ERTC courses. Instructors were in short supply. Initially many of the refresher course instructors were combat arms officers detailed to the course as an additional duty. It took some time for highly qualified officers to be secured for this effort. Training materials, equipment, and classroom facilities were always in short supply. Established primarily to provide engineer training to newly inducted individuals, the ERTC did not have the manpower or organization to develop officer training programs from scratch. It took time and considerable adjustment of resources for the problems of officer training to be resolved.

There were other factors that tended to affect the cadre of the ERTC and the soldiers they trained. In 1941, the first group of selectees received only eight weeks of training prior to being shipped to units participating in the Army maneuvers in Louisiana. The school shortened other cycles due to an unexpected influx of selectees. In September 1943, the 29th Engineer Training Battalion began the first 17-week training program. Every change in the length of the training program and every revision of the mobilization training plans caused major revisions of lesson material and complete changes in the scheduling of classrooms and ranges.

To a lesser degree, the change in command responsibility for replacement training also involved adjustments. Originally, Fort Leonard Wood was the Seventh Corps Area Training Center and came under the direction of that command. The Chief of Engineers was responsible for engineer doctrine and training, but Seventh Corps was the next higher headquarters. In 1942, Army responsibility for the ERTCs passed to the Army Service Forces (ASF). In 1944, the post was redesignated the Army Service Forces Training Center (ASFTC). Each change brought a different line of command, administrative, training, and logistical support. The ERTC/ASFTC often responded to training inspections from the War Department, the ASF, and the Chief of Engineers.

In the last year of the war, training at the ASFTC underwent some changes while other aspects of the center's effort remained constant. An increasing number of veterans of the European theater came to Leonard Wood for refresher training prior to shipment to the Pacific. The instruction and

management of this group differed from that given to newly inducted soldiers. In addition, the preactivation training for certain engineer units such as dump truck companies increased in scope. However, some training problems remained constant. Instructors continued to be in short supply, and facilities were limited, even with the end of divisional training in 1944. Standard issue equipment was often inoperable and the center was forced to use nonstandard equipment to complete training. This meant that soldiers were gaining proficiency on equipment which they did not use and was not covered by technical manuals. The designation of Fort Leonard Wood as one of three national basic training centers did nothing to ease the training pressures at the ASFTC.

The end of the war in the summer of 1945 turned the attention of the nation and the Army to demobilization. The trainee load at the center declined from 16,000 in July 1945 to 6,000 by the end of the year. The last training cycle for the Leonard Wood ASFTC began in January 1946 and ended in March. By that time the Army had shortened the training cycle to eight weeks and most unit and specialist training had been shifted to Fort Lewis, Washington.

On 31 March 1946 the ASFTC at Fort Leonard Wood closed its doors. In five years the ERTC/ASFTC had trained more than 170,000 engineer soldiers, both officer and enlisted. The post became an inactive installation serving National Guard units on summer training. However, only four years later another war, this one in Korea, brought engineer training back to the Missouri post. Since 1950, Fort Leonard Wood has had an unbroken history of training for the U.S. Army's engineers.

Sources for Further Reading

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SECTION II

Military Construction, Continental United States

The transfer of the military construction mission from the Quartermaster General to the Corps of Engineers was one of the most important events in the Corps' wartime history. The timing of the transfer was unintentionally dramatic: the President signed the legislation on 1 December 1941 and the law went into effect on 16 December 1941. Just as the nation geared itself for the greatest war in the 20th century, the Corps of Engineers launched the greatest military construction effort in American history.

The Corps was prepared. Its long history of civil works construction gave it a large work force experienced in the design, construction, and contracting of large-scale projects. More recently, its assumption of the construction mission for the Army Air Corps in November 1940 introduced the Corps to the requirements of this relatively new and soon to be prominent weapon of war. The legislation enacted in December 1941 culminated a period of intense maneuvering and debate, which is outlined in the first essay in this section. Both its long construction history and its recently proven ability to undertake new missions placed the Corps in a good position to assume the entire Army's military construction responsibilities.

In the months after December 1941, the Corps' mission grew to vast proportions. The most urgent and pressing construction projects had to do with defending American territory from enemy attack and building the facilities required to mobilize the country's vast resources of manpower and material. One of the first facilities needed was an office building for the huge staff that would direct the nation's worldwide war effort. Designed over a weekend and built with amazing speed, the Pentagon became the symbol of America's preeminent military power, which had its origins in World War II.

The Alaska Highway contributed to both defense of American territory and mobilization. Pushed through the wilderness of Canada and Alaska as a hasty pioneer road, it became a link between the lower 48 states and an American territory under very real enemy threat. Eventually the highway helped open up the resources of the northwestern part of the continent for the war effort. The Corps' role in this important war effort is the subject of the third essay in this section.

Construction of the Pentagon and the Alaska Highway were unusual projects notable for the attention they attracted. At Corps offices scattered throughout the continental United States, thousands of officers and civilians labored at the less glamorous, but no less important, projects that made the huge overseas war possible. Countless plain, even spartan barracks, hospitals, administration buildings, warehouses, rail sidings, ammunition plants, runways, and other types of facilities sprang up on camps, forts, and air bases all over the country. Corps of Engineers district and field offices did the work that made these less glamorous facilities possible. One important, but in most ways typical, Corps district, headquartered in Louisville, Kentucky, far from the battlefields of the Pacific or Europe, illustrates the important contribution that the Corps' field organizations made to the mobilization of the country.

The last essay covers probably the most secret project of the American war effort: the development and production of the atomic bomb. Because the project required such a huge construction effort for facilities that had to be designed from scratch and because of the intense need of secrecy, the Corps played a prominent and sometimes controversial role in what was clearly the greatest research and development feat of the war. Whatever the postwar controversies about the bomb and its use against Japan, veterans of the Pacific war remain convinced that it shortened the war and saved countless American lives.

The essays in this section on military construction in the United States only touch briefly on a few of the myriad of projects accomplished by the Corps during the war. They do illustrate, however, the broad scope of Corps' activities and their contribution to the war effort.

The Military Construction Mission

by Frank N. Schubert

At the outset of World War II, the mission of the Corps of Engineers underwent the most dramatic change that it had experienced in over a century. Beginning from traditional roles as sappers and builders of coastal fortifications during the American Revolution, the Corps had evolved into a major instrument in the development of the nation's water resources, the builder of dams, powerhouses, navigation locks and canals, and flood control works. In two quick steps during 1940 and 1941, the Corps became the construction agent first for the Army Air Corps and then for the entire War Department, replacing the Quartermaster Department, which had traditionally built the Army's facilities.

The expansion in the missions of the Corps came separately. They were not intended as two steps in a single process. Designation of the Corps to build facilities for the Air Corps in November 1940 was seen as a legitimate and adequate effort to reduce the massive workload that faced the Quartermaster Department, not as a prelude to further changes. In fact, the expanding construction requirements of mobilization were even seen as opportunities for expansion by bureaucracies outside of the War Department, and the Works Progress Administration (WPA)—a New Deal agency designed to create employment on public construction projects—had even made an unsuccessful bid to take over a substantial portion of Army construction in 1939.

During 1941, as war moved closer, the magnitude of the construction tasks ahead became increasingly clear. Meanwhile, questions emerged about the ability of the Quartermasters to carry out the program, and it became clearer that the problem of responsibility for this activity had to be resolved.

At the same time, the Air Corps program gave the engineers confidence with an unfamiliar and challenging mission. The Corps of Engineers already had significant experience with heavy construction, but the prewar work in rivers and

harbors and fortifications was not like the structural work supervised by the Quartermasters. War construction would include airfield pavement, which was a new and generally unfamiliar area to all concerned; industrial production lines; and troop facilities. By the early summer of 1941, the Corps' organization was immersed significantly in military construction, which was increasing while rivers and harbors work declined. The work of the Corps in fiscal year 1940, already dominated by the Air Corps mission, was 80 percent military.

Once a consensus was reached in the War Department that the Quartermasters were ill equipped to take on the job, the only question that remained was whether the mission should stay within the War Department and go to the Corps of Engineers, or be given to a new agency established just for the purpose. By the early summer of 1941, Michael J. Madigan, a canny millionaire construction engineer and special assistant to Under Secretary of War Robert P. Patterson—"an adviser," according to Lenore Fine and Jesse Remington, authors of the official volume on Corps of Engineers construction in the United States, "who knew the score in the public works construction game"—was at work trying to figure out how to resolve this question about who was responsible for military construction. Patterson was disturbed by reports of slow progress; Madigan had complaints about two systems of regulations and bookkeeping.

Michael J. Madigan, special assistant to the Under Secretary of War, testifies before a Senate subcommittee.

Madigan's evaluation of the situation for the Under Secretary of War, dated 15 August 1941, is the key document in the evolution of the decision to move the construction mission to the Corps of Engineers. Madigan's report, so significant in Corps of Engineers' history, was an unprepossessing "Memorandum to the Under Secretary of War," printed from

a stencil for limited distribution as was the usual practice in those days before photoduplication. It was nine pages long with eight brief annexes, one of which was a two-paragraph draft of a law designating the Chief of Engineers as responsible for "the direction of all work pertaining to the construction, maintenance, and repair of buildings, structures, and utilities for the Army, including acquisition of all real estate and the issuance of licenses in connection with Government reservations." Another annex listed applicable statutes and six annexes analyzed the construction programs of the Corps of Engineers and the Construction Division of the Quartermaster Department.

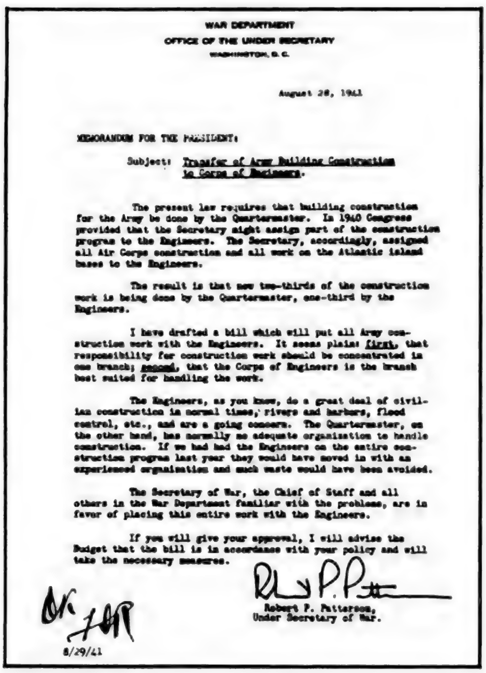
The main body of the report emphasized the duplication of construction effort on a national scale, resulting, according to Madigan, in "inefficiency, lack of coordination, and confusion, particularly in the minds of the public which must deal with two separate agencies with varying procedures in one department." Madigan believed consolidation under the Corps of Engineers would end competition for materials, personnel, and construction firms; maximize use of technical personnel; save money; and increase efficiency.

About half of the report was devoted to why the Corps of Engineers should be in charge. While Madigan had a list of eight reasons, overall they stressed the construction experience of the Corps, including success with its recently acquired mission of construction for the Air Corps, and its decentralized system of division and district offices. Madigan recommended against creating a new organization for the work. Establishing new agencies, he believed, always led to difficulties in defining their status and the scope of their activities, jurisdiction, and functions. He thought it would be much easier to transfer Quartermaster Construction Division functions and people—many of whom were in fact engineer officers—to the Corps of Engineers, without disrupting construction work and other Quartermaster functions that were unrelated to construction.

After reading and approving Madigan's report, Patterson moved fast. On the same day that Madigan delivered the paper, Patterson recommended to Secretary of War Henry Stimson that the Corps get the job. Stimson, in his turn, was not one to drag his feet. He approved it the next day.

Then Madigan met with the Chief of Staff, General George C. Marshall, who was inclined to want a separate construction corps. Madigan later recalled that he convinced Marshall by saying: "Every member of Congress knows the Chief of Engineers by name. If you want to throw away the best political contact anyone ever had with Congress, I can't stop you." After Marshall agreed, Madigan also persuaded him not to order a staff study so that the proposal would not be examined to death. Marshall countered by asking Madigan to handle the defense of a bill before congressional committees. Madigan assented. Army officers would not have to get involved.

Meanwhile Stimson got President Roosevelt to approve the proposal. Staff work was indeed much simpler in those days. Stimson carried Patterson's "Memorandum for the President, Subject: Transfer of Army Building Construction to Corps of Engineers" over to the White House, where the President scrawled "OK FDR" in the lower left-hand corner of the one-page note. In it, Patterson had concluded that construction should be in one branch, and that branch should be the Corps of Engineers. The nub of the argument was summed up in one paragraph:



WAR DEPARTMENT
OFFICE OF THE UNDER SECRETARY
WASHINGTON, D. C.

August 28, 1941

MEMORANDUM FOR THE PRESIDENT:

Subject: Transfer of Army Building Construction to Corps of Engineers.

The present law requires that building construction for the Army be done by the Quartermaster. In 1940 Congress provided that the Secretary might assign part of the construction program to the Engineers. The Secretary, accordingly, assigned all Air Corps construction and all work on the Atlantic island bases to the Engineers.

The result is that now two-thirds of the construction work is being done by the Quartermaster, one-third by the Engineers.

I have drafted a bill which will put all Army construction work with the Engineers. It seems plain: first, that responsibility for construction work should be concentrated in one branch; second, that the Corps of Engineers is the branch best suited for handling the work.

The Engineers, as you know, do a great deal of civilian construction in normal times, rivers and harbors, flood control, etc., and are a going concern. The Quartermaster, on the other hand, has normally no adequate organization to handle construction. If we had had the Engineers on the entire construction program last year they would have moved in with an experienced organization and much waste would have been avoided.

The Secretary of War, the Chief of Staff and all others in the War Department familiar with the problems, are in favor of placing this entire work with the Engineers.

If you will give your approval, I will advise the Budget that the bill is in accordance with your policy and will take the necessary measures.

Robert P. Patterson,
Under Secretary of War.

OK FDR
8/29/41

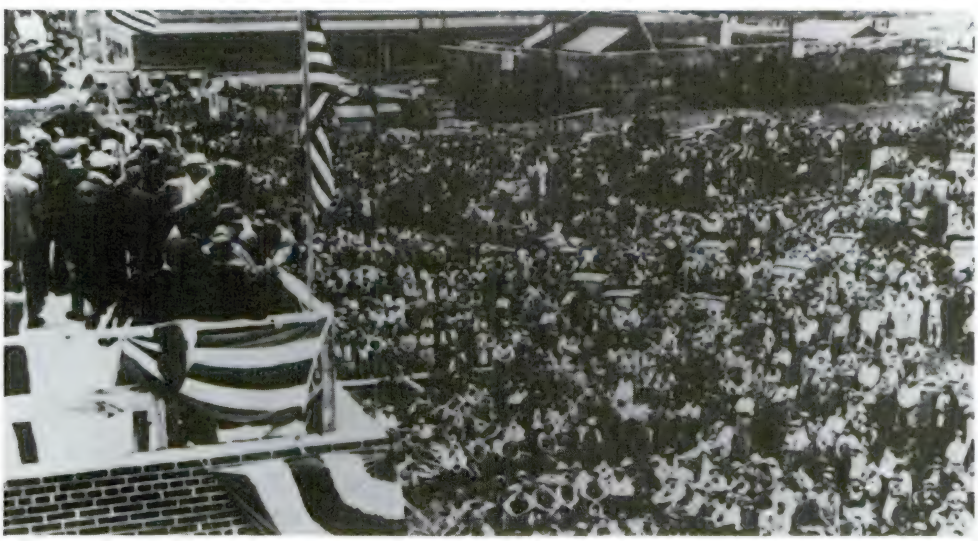
Memo on transfer of Army building construction to the Corps of Engineers, 28 August 1941.

> The Engineers, as you know, do a great deal of civilian construction in normal times, rivers and harbors, flood control, etc., and are a going concern. The Quartermaster, on the other hand, has normally no adequate organization to handle construction. If we had had the Engineers on the entire construction program last year they would have moved in with an experienced organization and much waste would have been avoided.

The assertion that followed, that "the Secretary of War, the Chief of Staff, and all others in the War Department familiar with the problems, are in favor of placing this entire work with the Engineers," was not true. The Quartermaster General, Lieutenant General Edmund B. Gregory, was actually kept in the dark about the impending transfer measure until after Roosevelt had initialed the memo. Once he found out, he certainly disagreed, arguing that construction in a theater of operations, an engineer responsibility, was unlike routine Zone of the Interior construction, and the combination of these disparate functions would redound to the disadvantage of both the Corps of Engineers and the Army. He took his dissent to Chief of Staff Marshall but no further. He was a soldier and never made public his disagreement.

Construction industry leaders were not excited about the change. AGC, the Associated General Contractors of America, took no position on the matter. *Engineering News-Record*, the major trade weekly, was wary at first because its editors thought the Corps of Engineers would revert to in-house design and engineering. However, Lieutenant General Eugene Reybold, who was Chief of Engineers, gave assurances that the government's way of doing business would not change.

After hearings and debate that went through much of the autumn, Congress passed a bill authorizing the change that



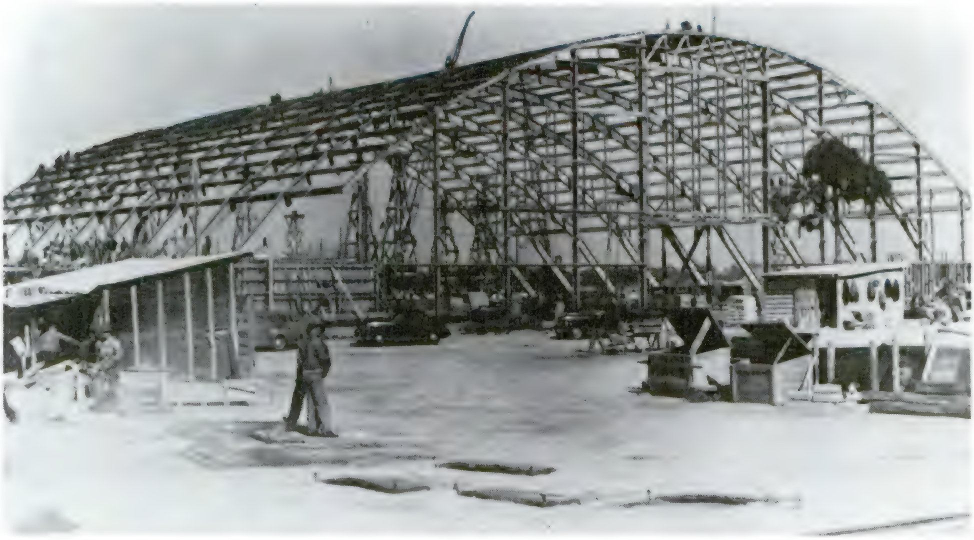
Brigadier General Brehon B. Somervell addresses construction workers at the St. Louis Ordnance Works.

President Roosevelt signed into law on 1 December 1941. By that time, planning for consolidation was already months along. Brigadier General Brehon B. Somervell, the ambitious Corps of Engineers officer who was in charge of the Construction Division in the Office of the Quartermaster General, drafted the plan. Somervell said the new mission represented "the greatest change of activities of the Corps in its entire history." His proposal envisioned different division boundaries for military work than for civil works, which followed major river basins.

The change was implemented on 15 December, eight days after the Japanese attack on Pearl Harbor. Two systems and teams had to be combined to work together. Major General Thomas M. Robins, Chief of the Construction Division in the Office of the Chief of Engineers, became responsible for all Army construction, including the declining civil works program. This arrangement lasted until late 1943, when Robins, who had a reputation for "sound judgment, cool-headedness, and tact," became the Deputy Chief of Engineers. At that time, military and civil works construction were split into separate divisions, starting an arrangement that continued into the postwar years.

While the change at the headquarters level took place in a very short period of time, the transition in the field was controlled so it would not happen too quickly. Quartermaster-run projects were turned over to the Corps of Engineers gradually, in accordance with the suggestion made by Robins that no more than one major project be turned over in each Corps district within a given week. Meanwhile, in keeping with the long-standing engineer approach, Robins spread authority to the field, allowing division engineers to execute contracts worth up to $5 million and approve nearly all plans and specifications. He authorized districts to approve contracts up to $2 million and prepare most designs. He also put responsibility for real estate, repairs and utilities, labor relations, and construction operations out to the field. As General Reybold said in March 1942, "The Army engineers are operating on the principle of decentralization."

The merger process was completed by the end of February 1942. According to a House of Representatives Military Affairs Committee report, it was done "with a minimum of



Hangar under construction at MacDill Field, Florida, 22 January 1942.

disturbance and without any disruption to the work whatever." Organizational adjustments continued through 1942, and to a lesser extent into later years, but overall the new arrangement proved up to the task. And the task was big! To describe it, General Reybold said, "I must borrow a word from Hollywood: the job is colossal." And it dwarfed even the Panama Canal and the World War I emergency construction program of 1917–1918. "In urgency, complexity, and difficulty, as in size," Reybold said, "it surpassed anything of the sort the world had ever seen."

Construction peaked quickly after the Corps got the mission. In 1942 almost 85 percent of the nearly $11 billion program was completed. Then came its rapid decline, as emphasis moved from construction to production and from home front to overseas.

By early 1942, when the transition in the field began in earnest, the divisions and districts of the Corps of Engineers already had substantial experience with transfers of partially completed projects. For example, Philadelphia District, where the acceptance of the military mission turned a $6 million coastal fortification project at the end of 1941 into a program worth over $111 million in a year, was ready even before the President signed the transfer bill. On 17 October 1941, the district published a memorandum listing all Quartermaster projects to be assumed by the Corps.

The organizational readiness of the Corps for the change stemmed to a large extent from experience with the earlier transfers of Air Corps facilities. In the Omaha District, between August 1940 and March 1941, the Quartermasters gradually released 81 Air Corps projects to the Corps of Engineers. There, Quartermaster employees assured a smooth transition, and many of them went to work for the district office along with their projects. In the Louisville District, the transition was also underway. However, it involved a more complex series of changes. This district along the Ohio River had started construction for the Civil Aeronautics Administration (CAA) in October 1940 as well as airfield and training school work for the Army Air Force in November.

The changeovers on these projects were multiple, involving New Deal agencies as well as the Army. At Godman Field at Fort Knox, the Quartermasters had started construction with WPA labor in January 1940. In Galveston District, with projects coming in from both the CAA and the Quartermasters, the district established separate groups to handle each. Both routinely worked seven-day weeks.

Transitions still took place with minimum disruption. The general procedure in Louisville was to appoint former constructing quartermasters at projects as area engineers, changing only the chain of command so that they reported to the district engineer instead of to the Quartermaster Department. During the peak period in 1942, "the magnitude of mission expansion was almost overwhelming" in Louisville, with daily expenditures of over $1 million, a sum almost equal to what the district had spent in entire years on civil works before the flood control projects.

In other districts as well, the turnover involved New Deal work relief agencies as well as the Army. The Connellsville, Pennsylvania, airfield began as a WPA project in 1935. It was converted to a military base by Quartermaster officers in 1938–1940 and finished by the Pittsburgh Engineer District. For the prisoner-of-war internment camp at Crossville, Tennessee, Nashville District engineers dismantled Civilian Conservation Corps buildings at Wartburg and Jamestown and transported them to the camp site.

In the Portland District, where the earliest military work included supervision of WPA airport projects, the Portland

airport started with WPA funds and evolved into a group-sized military aviation base. There military experience within the district was virtually nonexistent when the war emergency started, and the district had very little to fall back on. As District Historian William Willingham wrote, "textbooks on road-building plus an occasional inspector loaned from the Bureau of Public Roads proved helpful. . . ."

No sooner was the transition into the mission completed than its decline became noticeable. From placement of over $700 million worth of construction in the peak month of July 1942, the level of activity dropped to $150 million only one year later. The war was far from over, but the stateside construction that was needed to support the effort was largely in place. Successful and prompt accomplishment of this new mission brought the Corps of Engineers a reputation for flexibility and validated its practice of decentralizing mission execution to its divisions and districts. On the local level, engineer districts repeatedly took over work relief and Quartermaster jobs and completed them successfully. They proved that the decision to assign military construction to the Corps was a sound one.

Sources for Further Reading

The best book on Corps of Engineers construction during World War II—and the major source of this essay—is Lenore Fine and Jesse A. Remington, *United States Army in World War II. The Technical Services. The Corps of Engineers: Construction in the United States* (Washington, DC: Office of the Chief of Military History, 1972).

A number of histories of engineer districts provide information on the impact of the new mission on the field organization of the Corps of Engineers.

Constructing the Pentagon

by Janet A. McDonnell

During the first half of 1941 as the War Department stepped up its mobilization program, it faced the increasingly acute problem of providing enough office space for its personnel. The government had taken over apartment houses, warehouses, residences, and garages to accommodate its forces. By summer 1941, the War Department numbered over 24,000 civilian and military employees housed in 17 buildings scattered throughout Washington, DC, with a total space of 2.8 million square feet. The number of employees was expected to reach 30,000 by 1 January 1942. Storage space for War Department records was also in short supply. The War Department already devoted 650,000 square feet to storage, and requests had come in for an additional 300,000 square feet. In response, the Public Works Administration proposed to erect temporary buildings to ease the office shortage. However, Brigadier General Brehon B. Somervell, Chief, Construction Division, Office of the Quartermaster General, preferred to build one building for all War Department employees.

Recognizing the severity of the problem, on 14 July 1941 President Franklin D. Roosevelt transmitted to Congress a proposed appropriation for the Public Buildings Administration, amounting to $6.5 million to be spent for the construction of temporary structures in or near Washington, DC, for the use of the War Department and other agencies engaged in the national defense effort. This proposal was referred to the Deficiency Subcommittee of the House Committee on Appropriations, which held hearings on 17 July 1941. When the estimate for temporary structures came before the subcommittee, Representative Clifton A. Woodrum of Virginia suggested that the War Department find an overall solution to its space problems. The subcommittee was not satisfied with the proposal and requested that Brigadier General Eugene Reybold, Assistant Chief of Staff of the Army G–4, investigate the feasibility of constructing a building on

land under the War Department's jurisdiction in Arlington, Virginia.

On Thursday evening, 17 July 1941, Somervell called George E. Bergstrom, a California architect and former president of the American Institute of Architects who was currently a civilian in Somervell's Construction Division, and Lieutenant Colonel Hugh J. Casey, an engineer also in that division, to his office. Somervell informed them that by 0900 Monday morning he wanted basic plans and an architectural perspective for an office building to house 40,000 persons.

Somervell originally envisioned a modern four-storied structure with no elevators (to conserve needed war materials) that would house all War Department activities. He planned to locate the huge building on the site of the old Washington-Hoover airport in Arlington County on the Virginia side of the Potomac River, however, later inspection revealed that the airport site was in the river's floodplain. On Reybold's advice, Somervell changed the proposed location to a 67-acre tract further north and west, the former Department of Agriculture experimental station, Arlington Farms, near the entrance to Arlington National Cemetery. He reduced the height to three stories so that the proposed building would harmonize with the surrounding Arlington National Cemetery and the Lincoln Memorial.

On Monday morning, as instructed, Bergstrom and Casey presented Somervell with a plan for a building with 5.1 million square feet of floor space, twice as much as the Empire State Building. Fitted to the five roads surrounding it, the building would have five sides (hence Pentagon). Somervell proposed to construct the building along with parking for 10,000 cars, roads, and landscaping for an estimated $35 million. To conserve steel for the war effort, the building would be constructed of reinforced concrete. Most of the interior office space would be open with partitions, and only top officials would have private offices.

The next day, 22 July 1941, the plans went to Secretary of War Henry L. Stimson who eventually approved them. The plans also went to the Deficiency Subcommittee of the House Committee on Appropriations, which reconvened on 22 July. General Reybold presented his arguments before the committee and then introduced General Somervell who

outlined his plan for constructing, under War Department jurisdiction, a building with a gross interior office space of roughly 5 million square feet on government land known as Arlington Farms. The cost of construction, he explained, would be roughly $7.00 per square foot or $35 million, plus another million for the parking area.

Somervell and other supporters justified the project on the basis of the need for increased efficiency. War Department employees would no longer waste valuable time traveling from one building to another to consult with each other. Efficiency would also increase because office workers would have more space. Supporters argued that the government would save $3 million annually in rent. They also argued that the new building would free up other public buildings that the War Department was currently occupying and release apartments for residential use again.

Sensitive to the severity of the space problem, Congress moved quickly on the proposal. The House Committee on Appropriations approved Somervell's proposal, as did the House Committee on Public Buildings and Grounds. On 24 July 1941, the Appropriations Committee submitted to the full House its First Supplemental National Defense Appropriation Bill for 1942 which included $35 million for the construction of a new War Department building in Arlington. A lengthy debate followed on the House floor. Opponents challenged the proposed project primarily on the basis of its tremendous size and cost. They argued that the building would consume labor and materials already in short supply, increase existing traffic problems, and be a white elephant after the war. Meanwhile, the Secretary of War, by a memorandum dated 24 July 1941, submitted the proposal to President Roosevelt for preliminary approval. FDR approved the proposal on 25 July. The House resumed debate on 28 July, approved the appropriations bill that afternoon, and sent it to the Senate.

The Senate Appropriations Committee opened its hearings on 31 July 1941. The National Capital Park and Planning Commission submitted to the committee a critical report on the proposed building. Chairman of the National Capital Park and Planning Commission Frederic A. Delano, the President's uncle, believed the project would damage the

"dignity and character" of the area around Arlington Cemetery and the Lincoln Memorial. Delano expressed his concerns to the President. In response, on 1 August, FDR sent a letter to the committee setting forth additional observations. FDR did not object to the Arlington Farms site; but he did want a smaller building, one that would accommodate only 20,000 employees, to minimize possible traffic and transportation problems.

When the Senate committee resumed its hearings on 8 August, Reybold, Somervell, and others testified in favor of the appropriation. Protests came from the DC Chapter of the American Institute of Architects, the National Association of Building Owners and Managers, and others. The Washington Commission on Fine Arts also opposed the project, arguing that the proposed location should remain open either as a park or an addition to Arlington National Cemetery. Gilmore D. Clarke, chairman of the Commission on Fine Arts, testified against the project observing that it would obscure the approach to Arlington National Cemetery and suggested that it be moved three quarters of a mile to the south to the site of the Quartermaster Depot which was under construction. The National Capital Park and Planning Commission representatives called for a smaller building.

The Senate committee reviewed alternate sites including a site three quarters of a mile southeast of the disputed Arlington Farms site, which would take care of the aesthetic objection. The War Department already owned this land and had designated it for a Quartermaster Depot. Somervell staunchly defended the original Arlington Farms site and argued that a change of location would mean scrapping plans already drawn, cause a month's delay, and add substantially to the building cost.

The Senate Appropriation Committee overwhelmingly endorsed the Arlington Farms site and reported the bill favorably without changing the language of the House bill. The Senate approved the bill on 14 August. The issue was not resolved, however, for the bill as passed failed to specify the size or design of the building. A few days later, FDR expressed concern that the proposed site would mar the beauty of Arlington Cemetery. Despite this concern, on 25 August he signed the appropriations bill that contained

the provision for the controversial War Department building but reserved the right to select a different location.

On 26 August, FDR met with General Somervell, George Bergstrom, Harold Smith, the director of the Bureau of the Budget, and the chairman of the National Capital Park and Planning Commission. He told them that he favored a smaller building on the Quartermaster Depot site and asked them to come to an agreement on this. At a press conference that day, he announced that the building would be located at the Quartermaster Depot site and should be half as large as originally planned. Two days later, in response, the Secretary of War, the chairman of the National Capital Park and Planning Commission, and the director of the Bureau of the Budget presented a joint memorandum to the President agreeing on major details of a building for 20,000 employees at the Quartermaster Depot site. The President approved this memorandum, and the depot was transferred to Cameron, Virginia. Somervell proceeded with the building at the new location with its original five-sided design, but he did not reduce the size.

Plans for the new War Department building proceeded rapidly. Bergstrom, assisted by architect David J. Witmer of Los Angeles, developed plans for a unique reinforced concrete building which would consist of five concentric pentagons, separated by light wells and connected by ten radiating spokelike corridors, two on each side. It would have five stories, occupy 34 acres, and include a 6-acre interior court, numerous ramps and escalators, a large shopping concourse on the first floor, cab stands and bus lanes, and parking for 8,000 cars. Somervell named Captain Clarence Renshaw as the project officer to direct the construction work. Renshaw had served as assistant constructing quartermaster in charge of building approaches to the Tomb of the Unknown Soldier and restoring the Robert E. Lee mansion.

Construction began on 11 September 1941 when the construction contract was awarded to a joint structure composed of three companies: John McShain, Inc. of Philadelphia; Doyle and Russell of Richmond; and Wise Contracting Company of Richmond. The contract was a cost-plus-fixed-fee contract with an estimated cost of over $31 million. With proposed floor space of 4 million square feet, it would be the

largest office building in the world. On 10 October, after construction had been underway for a month, Somervell presented the plans to FDR. Confronted with an accomplished fact, a month of construction underway and 1,000 men already at work, FDR gave his approval with one stipulation —that no marble be used—to minimize the cost.

The outbreak of hostilities on 7 December 1941 quickly changed the projected plans for completing the building. It became clear that the size would have to meet war needs. As predicted, the change in location added to the cost as did the requirement that the building be constructed for possible future use for records storage. Also, officials had decided to build more extensive water supply and sewage treatment facilities than required in order to provide such facilities for other federal buildings in the area, which also added to the cost. Somervell went back to the appropriations committees for additional funding.

The Pentagon went up rapidly during the winter of 1941–42. Architects for the project had little or no lead time. Bergstrom and Witmer were under intense pressure to deliver drawings, and sometimes construction actually outpaced planning. The contractors had three shifts working around the clock, and by December, 4,000 men were at work.

Work proceeded at a "record-breaking pace." Sand and gravel came from the Potomac River bottom. Early dredging

Northwest exposure of the Pentagon construction, 1 July 1942.

Construction of the river entrance to the Pentagon, 1942.

of what would be a scenic lagoon enabled barges to bring these materials directly to the site. A plant with a daily capacity of 3,000 cubic yards fed materials into batch trucks for mixing en route to points throughout the structure. Forms for concrete columns, walls, and floors were preassembled, marked, and reused. Forms for concrete facing on the interior courts were built in place, and to save time new ones were provided for each section and old ones were taken down and salvaged.

During the early months of the war, Major Renshaw, McShain, and Bergstrom faced several crises: failure by the rolling mills to deliver steel on time, a strike by plumbers and iron workers, and last minute decisions to increase the size of the building. Construction was also plagued by an unusually high accident rate. Yet they managed to keep the job on schedule. One side was completed by 29 April 1942 when the first occupants moved in. The basic shell and roof were finished within one year and the building was completed by 15 January 1943. As occupancy increased, pressure on space in Washington, DC, relaxed.

Wartime shortages forced some modifications. Officials avoided the use of critical materials whenever possible. Bergstrom's design for a concrete structural framework resulted in a savings of 43,000 tons of steel. Concrete ramps were substituted for passenger elevators. Drainage pipes were

Pentagon construction, northeast exposure, shows part of the south parking and access roads, 30 November 1942.

made of concrete. Ducts were produced from asbestos fibers; interior doors were made of wood. Bronze doors, copper ornaments, and metal toilet partitions were eliminated.

The Pentagon was the largest office building in the country at the time. It was at least two times the size of the Empire State Building and 50 percent larger than Chicago's Merchandise Mart. The National Capitol would fit into any one of its five pie-shaped sections. The design and construction of the building took only 16 months, although construction of such a structure would normally have taken four years. At its peak, the Pentagon housed nearly 33,000 workers (the average working population of a city of 100,000). Supporters predicted that the Pentagon would pay for itself in 8 to 14 years, based on a rental of the equivalent amount of office space in Washington, DC.

The frame was steel-reinforced concrete designed for floor loading of 150 pounds per square foot to meet the President's order that the building be suitable for records storage after the war. All outside exposed walls were monolithic architectural concrete, except the mile-around perimeter wall, which was faced with Indiana limestone. The building rested on 42,000 Raymond type (poured in place) concrete piles. Over 5.5 million cubic yards of earth were moved in grading. There was no unnecessary ornamentation, no fountains, no "marble

halls," and except for some 6-inch marble base and 10 pieces of marble stringer facing, no marble was used in the building at all.

Planners reduced landscaping to a bare minimum. It was confined to grading and planting of small trees, shrubs, and grass. Grading was the minimum required for safe road shoulders and the planting was the minimum required to prevent erosion and protect structures. The lagoon in front was not developed for landscaping purposes but resulted from the excavation of large quantities of material required for road and parking area fill.

Usable office floor area, not including such things as permanent corridors, ramps, concourse, stairways, bus terminal, cafeterias, and rest rooms, was 3,634,490 square feet or 58.3 percent of the gross 6,231,000 square feet, which compared favorably to other federal office buildings. There were 17.5 miles of corridors. The maximum walking distance from any point in the building to any other point was 1,800 feet (slightly more than ⅓ mile, roughly a 6-minute walk). In a conventional rectangular building of the same number of stories and equivalent floor space, the distance would be 30–50 percent greater.

Total costs amounted to $63,454,583, which included $49,957,653 for the main building and $13,496,930 for outside utilities (the power and heating plant housed in a separate building, access roads and parking lots, drainage and fills). The costs per square foot of floor area compared favorably with the corresponding figures for other federal office buildings. The gross cost per square foot of floor area was $7.86 as compared to Interior Department ($9.57) and Labor Department ($9.13). The net cost per square foot of office space amounted to $13.15.

The architects and engineer officers who designed and constructed the Pentagon produced one of the most innovative and unique structures of the war era. With this massive yet efficient structure, they not only resolved the problem of housing thousands of War Department employees during the war years; they also provided for future War Department needs.

Sources for Further Reading

The number of secondary sources dealing with the construction of the Pentagon is surprisingly small. The author of this essay drew primarily on Lenore Fine and Jesse A. Remington, *United States Army in World War II. The Technical Services. The Corps of Engineers: Construction in the United States* (Washington, DC: Office of the Chief of Military History, U.S. Army, 1972); William J. Webb, "Building the Pentagon in Arlington," *The Arlington Historical Magazine* (Volume 7, Number 4, October. 1984), pp 31–38; and Major Robert B. McBane, "The Pentagon Makes Sense" (reprint from *Army Information Digest*) in the U.S. Army Corps of Engineers History Office research collections, Military Files, General, I–8–3.

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Building the Road to Alaska

by John T. Greenwood

Today colorful travel brochures beckon tourists to drive the modern two-lane Alaska Highway from Dawson Creek, British Columbia, through the scenic Canadian Rocky Mountains and the historic Yukon, and on to Fairbanks and the natural wonders of Alaska—a distance of 1,500 miles. Before Japanese carrier aircraft devastated the U.S. Pacific Fleet at Pearl Harbor on 7 December 1941, no such highway existed nor was it likely to exist in the near future. But soon after Pearl Harbor, fears of the Pacific Northwest's vulnerability to Japanese attack prompted leaders in Washington and Ottawa to approve the emergency construction of a highway to Alaska. With the U.S. Pacific Fleet crippled and Canadians defending the British Commonwealth almost everywhere else but in western North America, a secure inland route was of the utmost importance to the defense of western Canada and Alaska.

ALCAN Highway

In February 1942 President Franklin D. Roosevelt approved plans for construction of a military road through Canada to Alaska. The State Department then asked Canada for permission to send two U.S. Army Engineer regiments to Whitehorse, Yukon Territory, and two others to Fort St. John, British Columbia. A two-phase construction program was outlined. Because the engineer units could get to work much more quickly, they would build the initial pioneer road. Civilian contractors working for the U.S. Public Roads

Brigadier General William M. Hoge commanded the Alaska Highway effort from February through May 1942 when the project was divided into the northern and southern sectors. (National Archives)

Administration (PRA) would then upgrade this road into a permanent highway. Colonel (later Brigadier General) William Morris Hoge, Corps of Engineers, would command the Canadian–Alaskan Military Highway project, soon to be known simply as the ALCAN (renamed the Alaska Highway in 1943).

While awaiting permission to move engineer units into Alberta, British Columbia, and the Yukon, planners in Washington were busy. Before the war, an inland route to Alaska had been intensely debated in Canada and the United States. Most of the field surveys and data collected focused on various routes in Alaska and on the preferred coastal options through British Columbia to the Yukon. These studies usually excluded the so-called "prairie" route of Edmonton–Fort St. John–Whitehorse. United States planners eventually chose this route due to its direct rail, road, and air access to the midcontinent and the Japanese threat to the coastal routes.

Because large parts of the area were unexplored, unmapped, and even unknown to local fur trappers and Indians, the initial route planning was done on large-scale 1:250,000 National Geographic Society maps and 1:1,000,000 aeronautical charts, and aerial photographs. At first there were no plans other than the specific requirement to link the airfields already established at Fort St. John, Fort Nelson, Watson Lake, and Whitehorse in Canada and Northway and Big Delta in Alaska. Built in 1940–41, these airfields made up the Northwest air ferry staging route to American and Canadian forces defending Alaska and western Canada.

The great distances involved, the poor communications and means of transportation, and the very difficult and rugged terrain determined how Hoge organized his construction forces. At first, there were no plans other than to link these airfields with roads. The mountains formed a 7,000-foot natural barrier, so he divided the project at Watson Lake, 600 miles north of Fort St. John, which would house the southern sector's headquarters. Hoge's main headquarters and those of the northern sector were co-located at the Yukon's capital of Whitehorse. This was a sound choice due to its good communications and transportation facilities and its location on the Lewes River, a branch of the extensive Yukon River system. Whitehorse also had an airport, was connected to Carcross and the Alaskan port of Skagway by the narrow-gauge White Pass & Yukon Railroad, and during the navigation season became a bustling river port.

From the very first, the physical separation of the two sectors and the difficulties of travel and communications along the designated route adversely affected Hoge's overall control. In May, the two sectors were completely separated, with Hoge taking over the northern sector and its four engineer regiments, and Colonel (later Brigadier General) James A. "Patsy" O'Connor assuming command of the three regiments then assigned to the southern sector. This division gave Hoge the far tougher and larger assignment—over 830 miles from Watson Lake, just over the British Columbia–Yukon border, to Big Delta, some 90 miles southeast of Fairbanks, plus the 72-mile extension of the Richardson Highway's Slana cutoff to the Tanana River.

On 3 March 1942 Hoge received his construction directive from the Office of the Chief of Engineers (OCE) and left Washington for Fort St. John the next day. This order laid out Hoge's mission and the authorities granted to accomplish it. Hoge was charged with surveys, construction of the pioneer road, and coordination with the PRA for location and construction of the permanent road that its contractors would complete. A 9,200-man provisional engineer brigade was established under Hoge's command with its headquarters at Whitehorse and included the 18th, 35th, 93d, 340th, and 341st Engineer Regiments (the 95th and 97th were added later), the 73d and 74th Engineer Companies (Light Ponton),

In the northern sector of the Alaska Highway, topographic engineer survey teams work with Public Roads Administration crews to mark locations for the clearing crews.

topographic survey companies from the 29th Engineer Topographic Battalion in the north and from the 648th Engineer Topographic Battalion in the south, and numerous attached units. The two light ponton companies were critical to success because, after the thaw and before bridges were built, their ponton ferries and floating bridges would be the only means of moving men and heavy equipment across the many formidable rivers and streams that crisscrossed the proposed route.

Of the many problems Hoge faced in February–March 1942, one of the first and most critical was where and how to place the engineer regiments astride the proposed road. The short construction season demanded haste, so it was important to get as many units working as soon as possible. After analyzing the problem, Hoge decided to use the few access points available—the north and south ends, Whitehorse, and Lake Teslin via Whitehorse—to break the road into digestible segments.

Two regiments—the 18th Engineer Regiment (Combat) (Lieutenant Colonel E. G. Paules) and, cadred from it, the 340th Engineer Regiment (General Service) (Lieutenant Colonel F. Russel Lyons)—were slated for Whitehorse. One regiment could work southeast toward the two units working from Fort St. John, and the other northwest toward Alaska.

The 18th Engineers began working north from Whitehorse in late April 1942. The conditions on the cleared but ungraded and unfinished road hampered the movement of men, equipment, and supplies. (National Archives)

By mid-March, however, Hoge concluded that four regiments were insufficient to complete the pioneer road in 1942. The deficiency was especially critical in the north. From Whitehorse to Big Delta, the road would run over 560 miles, and it was over 325 miles from Whitehorse to Lower Post near Watson Lake.

Thus, Hoge requested additional general service regiments and eventually received the black 93d, 95th, and 97th General Service Regiments after they were reequipped and upgraded from separate labor battalions. The 93d (Colonel Frank M.S. Johnson) was ordered to Whitehorse via Skagway and would work southward on the Whitehorse–Teslin sector. This allowed the 340th to skip farther south to begin work on the Teslin–Lower Post sector.

The 97th (Colonel Stephen C. Whipple) would land at Valdez, Alaska, in mid-May. While PRA contractors would eventually tackle the 119 miles of road southeast from the Richardson Highway at Big Delta to Tok Junction, the 97th Engineers would build the connector road from Slana to Tok Junction at the confluence of the Tok and Tanana rivers and then head southeast to join the 18th Engineers. A third black regiment, the 95th Engineer Regiment (General Service) (Colonel David L. Neumann), was added in April and

scheduled to arrive at Fort St. John early in June to work north toward Fort Nelson with the 341st Engineers (Colonel Albert L. Lane).

One of the two regiments going to Fort St. John had to move 250 miles north to Fort Nelson so it could build toward Watson Lake after the spring thaw. If it could not be moved, the mountainous 900-mile gap between Fort St. John and Whitehorse could never be conquered in a single working season. Lieutenant Colonel Robert D. Ingalls' 35th Engineer Regiment (Combat), along with the attached 74th Light Ponton Company and topographic companies, had to reach Fort Nelson before the winter snow-sled road from Dawson Creek turned to impassable muck.

Hoge's greatest worry was getting the regiment, with all of its heavy equipment and sufficient supplies, across the unbridged 1,800-foot-wide Peace River south of Fort St. John while the river ice could still support traffic. With the thaw, floating river ice would prevent the use of ponton ferries and floating bridges and retard any northward movement for several months. The movement of the 341st Engineer Regiment, which was then being formed from a cadre of the 35th, was not rushed.

Quartermaster and engineer supply officers were soon scouring western Canada for petroleum products and haulers to move them to Fort Nelson. The 35th had to carry 150 days of equipment, supplies, and spare parts, as well as 60 days of rations because Fort Nelson would only be accessible by air for some time after the thaw. Trainloads of equipment began arriving at Dawson Creek on 5 March. Five days later, the first elements of the 35th Engineers detrained at Dawson Creek for their 300-mile journey to Fort Nelson.

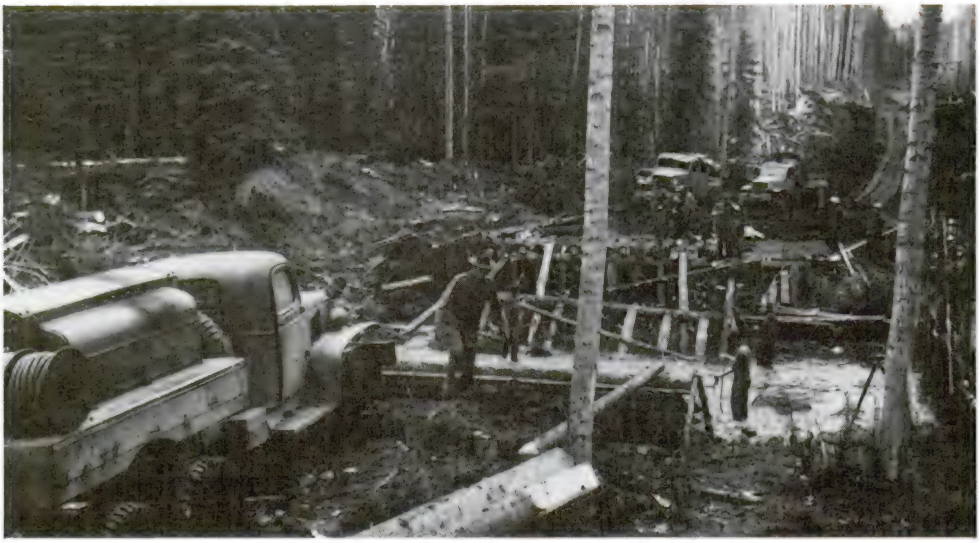
The engineers first insulated the Peace River crossing against sudden warming with a thick layer of sawdust and then reinforced it with heavy wooden planks. By late March 1,900 officers and men; over 900 tons of supplies and equipment; 429,000 imperial gallons of oil products; and carryalls, graders, power shovels, compressors, trucks, and ten 23-ton Caterpillar D-8 tractors had crossed the river and were trekking north toward Fort Nelson in temperatures as low as -35 °F. On 5 April the last elements reached Fort Nelson.

Hoge ranked the crossing of the Peace River and the winter march of the 35th Engineers among his most critical achievements. The project could then be sliced into six segments of roughly 250–300 miles each, which could be built separately and simultaneously. If the 35th had not reached Fort Nelson, the road could not have been finished in 1942.

As Hoge prepared his units to assault the Canadian wilderness, in Washington Army planners in the Services of Supply (SOS) were addressing a critical unanswered problem —how to provide sufficient fuel at an economical cost for the trucks that would use the completed ALCAN Highway and for the aircraft transiting the Northwest air ferry staging route. In May, Lieutenant General Brehon B. Somervell, the SOS commander, approved an entirely new engineer effort for the Canadian north—the grandiose, controversial, and costly Canadian Oil (CANOL) project. CANOL included oil wells at Norman Wells in the Northwest Territories, a 500-mile pipeline to Whitehorse, a refinery at Whitehorse transplanted from Texas, and various pipelines radiating from the refinery to Skagway and along the ALCAN to support trucking and aircraft operations as well as bases in Alaska.

During March and April, Washington's plans for the future supply of petroleum products from CANOL were of little importance to engineers who were confronting critical problems in route location as well as in construction planning and management. Much of Hoge's trouble arose because the project involved two separate federal agencies, the Corps of Engineers and the Public Roads Administration, each of which had separate chains of command from Washington to the project.

Through the first months, Hoge made little headway in locating the pioneer road in the more inaccessible areas. The lack of adequate maps and aerial photography until late June, combined with a paucity of detailed route information, especially about the rugged 640-mile section from Fort Nelson to Whitehorse that crossed the Rockies, equaled little success on route location. The surveys of the Alaskan International Highway Commission and the Alaska Highway Commission provided detailed routes between Big Delta and Whitehorse, but frequent public criticism of the ALCAN's route by Thomas Riggs and Donald MacDonald of the International



The 18th Engineers build a timber bridge across the Raspberry River north of Whitehorse, Yukon Territory, May 1942.

Commission forced restudies and delayed final location decisions on even these routes for several months.

To the south, placement between Fort St. John and Fort Nelson progressed little during March and into April because there were no planes for aerial surveys. As a result, Hoge and locating teams guessed about possible routes based on available information. Hoge finally hired Les Cook, a Canadian bush pilot from Whitehorse, to fly him and his key officers to search out locations for the road.

Hoge's rides with Les Cook broke the logjam. From Les Cook, Bill Hoge learned the secrets that allowed him to drive the road through the largely uncharted region. Les Cook pointed out the best crossing of the Rockies, 96 miles east of Teslin and 195 miles from Whitehorse with a summit of 3,100 feet. This route was unknown to local inhabitants, but its discovery through aerial reconnaissance was a key to the early completion of the highway. Lieutenant Colonel Reinder Schilsky of the 340th Engineers followed up this lead with a ground survey which firmly established the route from Teslin Lake to Watson Lake. By early June, the biggest question mark on this section of the road was erased.

Weather and ground conditions often prevented detailed ground reconnaissances. On the northern sector, 12 PRA

The Caterpillar D-8 bulldozer allowed engineer regiments to clear, cut, fill, and grade the pioneer road faster than had been planned.

locating teams worked southeast and northwest from Whitehorse with detachments of Major Frank Pettit's topographic survey company from the 29th Topographic Battalion. All of the teams desperately needed aerial photographs, but photographic planes were not to begin operating effectively until June. Even then the negatives had to be flown to Seattle for developing because the proper equipment was lacking. Only in July did the locating teams have aerial photos.

Ground and aerial reconnaissances continued on all sections throughout the summer, but the engineer clearing crews and their D-8s were right on the heels of the marking teams. Efforts to place the pioneer and permanent roads in close proximity ended when the PRA locating parties could not provide detailed survey information far enough in advance of the clearing parties to prevent delays. The Army engineers worked against a tight deadline dictated by the seasons and an equally tight set of specifications and orders on the kind of road they were to build. The final decision on location of the pioneer road and its specifications always remained the prerogative of the sector commander. The real culprit in the location problem was the 23-ton D-8 bulldozer which allowed the engineer clearing teams to push ahead so much more rapidly than anyone thought possible in the spring.

During a visit to Anchorage while he was still in overall command of the project, Bill Hoge was asked how he was going to build the road. He answered, "with six machines of 1,000 men each"—his engineer regiments. On the Whitehorse sector, after May, Hoge had two white regiments, the 18th and 340th, and two black regiments, the 93d and 97th. However, the 93d and 340th sat in Skagway and the 18th worked slowly north from Whitehorse through April and into mid-May awaiting the arrival of their heavy equipment that was stalled in Seattle.

Upon receiving its equipment, the 93d moved to Carcross from whence it built an access road east to Jake's Corner and then worked its way across heavily wooded terrain toward the Teslin River. The 50-mile sector from Whitehorse south to Jake's Corner was left for the PRA's civilian contractors. While the 340th's personnel leap-frogged the 93d, its heavy equipment was shipped via the Yukon and Teslin rivers and Teslin Lake to Teslin. From there, it began building toward Watson Lake and Lower Post on the Liard River, 188 miles to the east, to link up with the 35th that was working to the west and then northwest on its 337-mile leg from Fort Nelson. The 97th landed at Valdez in mid-May and began working from Slana in mid-June.

The 18th Engineer Regiment arrived at Whitehorse in early April. Despite a lack of heavy equipment, the 18th went to work north of the city with small D-4 tractors, fresnoes, and hand tools, and set up a training school for D-8 operators for itself and the 93d and 340th Engineers. In a pattern that all units on the road would follow, after April the 18th Engineers lived in tents, moved constantly (174 major moves in 10 months), and worked three 8-hour shifts, seven days a week. The soldiers cursed the endless sub-Arctic summer nights that permitted such work schedules, the voracious horse-sized mosquitoes and flies, monotonous Army B-rations, and the lack of supplies and spare parts. Yet they steadily pushed their camps and roads forward toward the Alaska border.

Each regiment organized itself differently for road work. The three platoons of each company provided a structure readily adapted to three-shift operations. Two basic approaches were used—leap-frogging and the "train." In the

former, a company was assigned a specific sector of 5 to 15 miles behind the D-8s of a clearing task force. Working as fast as it could, living in tents, and fully mobile, the company would complete all the work on that particular sector from clearing away timber to placing culverts and grading the road. As it prepared this section, the companies that it had leap-frogged would finish their sections and move ahead to new sections. When the company was finished, it leap-frogged to the front of the column again, and the process started all over.

In the train method, the regiment was broken up into companies that were assigned to specific tasks—the clearing crew, then the company which built log culverts and small bridges, followed by the ditching and rough grading crew, which also placed corduroy if necessary. Then came the rest of the regiment strung out over 30–40 miles of road widening, graveling, smoothing, and cutting grades and curves.

With only four good months in the construction season, no one worried about the subtleties of normal road building. The engineers' job was to complete the pioneer road as fast as possible. No time could be wasted for carefully constructed subcourses, gentle curves, or easy inclines.

In the north, Hoge was continuously on the go. He personally tested the radii of the curves until he was sure that the trucks and equipment could get around them without backing up. He emphasized that the job had to be done quickly. Sophistication would come with the PRA's permanent road. Hoge was once quoted as telling a subordinate: "Your road is too good, too wide, and too short."

Hoge's approach to construction was simple and direct. Early on he had declared the standard for clearing to be 50 feet on either side of the center line, with a road surface 18 feet wide, 5-foot shoulders, maximum grades of 10 degrees, and easy curves. The key to Hoge's plan was his heavy equipment, the air compressors and power tools, motor graders, scrapers, and especially the D-8s, which had three basic functions—clearing, cutting and filling, and grading the pioneer road. Once a suitable number of the big "Cats" were on line—and each regiment eventually had 20 of them to team with its 24 medium D-4s—10 to 12 D-8s could clear 2 to 3 miles of 100-foot right-of-way through solid forest in

Timber box culverts were used in great numbers along the Alaska Highway. Timber was plentiful and used generously for every possible application.

a day. So successful were these clearing teams that they were soon on top of the location and staking teams. Because of this, engineer and PRA coordination on route location was foreclosed, with unfortunate consequences.

Despite rainy weather in May and June and continuing deficiencies in equipment and supplies throughout the summer, the engineer regiments steadily drove their pioneer roads into the Canadian wilderness. By early June over 10,000 Army personnel were at work along the road—O'Connor's southern sector had 4,354 officers and men in its three engineer regiments and attached units while Hoge's four regiments had 5,806 officers and men. Few obstacles slowed construction except the major water courses, such as Slim's River, which required the 18th Engineers to build a 1,040-foot pile stringer bridge and the 340th's bridge over the Rancheria River. The effort expended on bridges and culverts was significant—in the 95 miles from the Aishihik River to Kluane Lake, the 18th Engineers built 25 stringer bridges, an A-frame at Aishihik, 2 pile stringer bridges, and 138 timber box culverts. Luckily, timber was never in short supply.

Road Construction May-July 1942 (cumulative total in miles)			
	Located	Completed	Under Construction
Northern Sector			
May	78	24	30
June	293	161	87
July	480	353	98
Southern Sector			
May	75	28	21
June	177	84	28
July	378	258	85
Total by end of July	**858**	**611**	**183**

Alaska Highway road construction: May–July 1942.

Local construction experts repeatedly warned Hoge that muskeg—basically soggy peat bogs—would seriously curtail his progress. However, careful location of the road away from muskeg, where possible, or clearing and allowing the muskeg to dry out usually overcame this problem.

While clearing and drying may have worked with muskeg, it was absolutely the wrong approach for the permanently frozen subsoil, or permafrost, that lurked beneath the surface on large stretches of the route in the north. Isolated trouble spots first appeared on sections of road that the 18th Engineers were clearing around Kluane Lake north of Whitehorse. Dry and passable one day, the next day they were muddy and impassable.

No sooner had the 18th Engineers mastered this area than both it and the 340th to the south ran into extensive stretches of permafrost. Progress plummeted to less than a mile a day during August and into September as axes, shovels, and musclepower replaced the D-8's steel and horsepower. Hoge's swath-cutting technique was completely wrong.

Engineers attempt to undo the damage of permafrost on the southern sector of the Alaska Highway. When clearing crews ripped off the vegetation that insulated the frozen ground, the resulting ooze hampered work.

The D-8s simply ripped the vegetation cover off of the permafrost, thus accelerating the melting and creating the muddy areas. Rather than bulldoze a path through the timber and scrub, the units now had to cut the timber by hand, make a corduroy mat of timber and branches, and then cover this mat with gravel and dirt to insulate the permafrost. Only then could they resume building the road on top of the corduroy insulating blanket.

The proper techniques for construction in Arctic and sub-Arctic permafrost areas were then known to few engineers in the United States. Laboratories such as the Corps' Cold Regions Research and Engineering Laboratory (CRREL) would not come into existence until years later to search for solutions to problems such as those faced and solved by trial and error every day during the construction of the Alaska Highway.

By midsummer of 1942, the Engineers were building a road of a much higher standard and much more quickly than envisioned in the original plans. The pioneer road was really a well-graded and drained two-way road for most of its distance, not the one-way access road suitable only for the use and supply of the troops. The PRA contractors, who were to build the permanent road, had progressed little beyond

Corduroy roads, such as this one built by the 93d Engineers near Little Atlin Lake, Yukon Territory, were necessary in boggy areas and to cover permafrost sections to prevent thawing.

establishing their camps, gathering equipment, and initiating work. It now appeared likely that the road would be ready to Fort Nelson by 15 September and to Watson Lake and Northway by 1 December. Winter traffic to Alaska could use the road from 1 December through the spring thaw of 1943 once sufficient support facilities and services could be established.

By early August, however, another factor in Washington affected the OCE's increasingly militant approach to work on the highway. OCE reminded O'Connor and Hoge that their jobs were to build a pioneer road and to reach agreement with the PRA if possible, and if not, to refer the decision to Washington. General Somervell was especially sensitive to renewed public criticism of route selection and construction, but this was especially bothersome one month after House and Senate investigations of the ALCAN project.

Based on OCE's latest directives, both Hoge and O'Connor issued new construction instructions to the 430 engineer officers and 10,100 enlisted men who were now working along the road. By late August, 525 miles had been completed in the north and another 116 miles were in progress, 312 miles were usable, and 233 miles were being built between Fort St. John and Watson Lake. However, in a major reorganization

at the end of August, Bill Hoge was relieved of command of the northern sector and both sectors were combined under O'Connor.

The early completion of the highway, the continuing criticism and congressional inquiries about the route selection, and Somervell's own plans prompted his visits to Canada and Alaska from 17 to 22 August. He was probably more concerned about his pet Canadian Oil (CANOL) project than the highway, but the two were increasingly intertwined now that the highway neared completion. Petroleum products from the CANOL refinery at Whitehorse were essential for the economical and efficient operation of Army trucking operations on the long haul from Edmonton to Alaska and for aviation operations along the staging route.

When Somervell arrived in the Whitehorse sector after a brief stop with O'Connor, he found plenty to dislike about Hoge's operation. After looking over the congested and uncomfortable Whitehorse for two days, Somervell decided things were a mess. The White Pass & Yukon Railroad to Skagway, the housing, and supplies were all inadequate, and Hoge's whole concept and operation were unacceptable.

Removal of Bill Hoge stemmed more from Somervell's personal animosity and grandiose plans than from any substantive reason or lack of performance. Hoge survived his firing and went on to hold a number of important commands during and after World War II, retiring in 1955 with rank of full general as Commander-in-Chief, U.S. Army Europe, the American ground component of the North Atlantic Treaty Organization (NATO).

On 4 September, Somervell established the Northwest Service Command to preside over his new empire in the northwest, including CANOL and the services supporting the soon-to-be-opened highway from Dawson Creek to Fairbanks. The men, material, supplies, equipment, and support for which Hoge had fought so hard were lavished upon O'Connor's new command in the months to come.

The road from Fort St. John to Whitehorse was completed on 24 September when the 340th and 35th Engineers met, and that section through to Alaska was passable when the leading D-8s of the 97th and 18th Engineers finally met on 25 October at Beaver Creek, a few miles shy of the Alaska

The meeting of the bulldozers at Beaver Creek, Yukon Territory, 25 October 1942 (left: Corporal Refines Sims, Jr., 97th Engineers; right: Private Alfred Jalufka, 18th Engineers).

border. The Alaska Highway was officially opened to U.S. Army truck traffic in a Canadian–American ceremony at Soldier's Summit on the west shore of Kluane Lake on 20 November 1942. The first truck from Dawson Creek reached Fairbanks the next day.

With roadside service facilities and communications established, Army truck traffic flowed between Edmonton and Fairbanks and to all points in between during the winter of 1942–43. The 18th and 93d Engineers left the road in January 1943, and the 35th, 95th, 97th Regiments and the 73d Light Ponton Company departed in February. The 340th and 341st Regiments and the 74th Light Ponton Company remained well into 1943 to assist the PRA contractors who went to work that spring straightening and improving the previous year's pioneer road and putting in permanent bridges. Army Engineers assigned to the Northwest Service Command's Northwest Engineer Division and its various districts then managed the CANOL project and its pipelines (fully operational in April 1944), added the Haines cut-off in

Sector Responsibilities (mileage as built)		
Regiment	**Sector**	**Mileage**
341/95 EGSR	Fort St. John — Fort Nelson	256
35 ECR	Fort Nelson — Lower Post	337
340 EGSR	Lower Post — Teslin	188
93 EGSR	Teslin — Jake's Corner Jake's Corner — Carcross	62 35
PRA	Jake's Corner — Whitehorse	54
18 ECR	Whitehorse — Beaver Creek	298
97 EGSR	Beaver Creek — Tok Junction Slana Cutoff	122 72
PRA	Tok Junction — Big Delta	119
Total Built	**Fort St. John — Big Delta**	**1,543**
Already Completed	Dawson Creek — Fort St. John Big Delta — Fairbanks	48 94
Total	**Dawson Creek — Fairbanks**	**1,685**

EGSR = Engineer General Service Regiment
ECG = Engineer Combat Regiment
PRA = Public Roads Administration

Alaska Highway sector responsibilities.

1943–44, and oversaw maintenance and improvement of the Alaska Highway until 1946 when the Canadian government assumed full responsibility.

Today the Alaska Highway is a vital and vibrant commercial artery that supports the settlement, development, and well-being of northern British Columbia, the Yukon, and much of Alaska. As such, the highway is a permanent memorial to the seven "machines of 1,000 men each" and thousands of other U.S. and Canadian soldiers and civilians who built this road through uncharted wilderness in seven short months in 1942.

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The Louisville Engineer District

by Charles Parrish

At the time of the Japanese attack on Pearl Harbor and the subsequent entry of the United States into World War II, the Corps of Engineers was caught up in the throes of reorganization. Only days before, the President had ordered merger of the Construction Division of the Quartermaster Corps into the Corps of Engineers. In December 1941, the Louisville Engineer District, then engaged in the initial phase of constructing several local flood protection projects, suddenly got responsibility for managing a crucial military construction mission, receiving perhaps its most demanding challenge ever. However, the district was not totally unprepared for this bold mission. The Corps had been assigned part of the airport construction program for the Civil Aeronautics Administration (CAA) in October 1940 and one month later was given the job of constructing installations for the Army Air Force to provide airfields and training schools for thousands of pilots.

The Louisville District's activities in the airfield construction program for the CAA involved projects at Kokomo, Indiana, and at Bowling Green and Paducah, Kentucky. In addition, the district had undertaken construction at Standiford Field in Louisville adjacent to land the county had made available to Vultee Aircraft Corporation and Curtiss–Wright Corporation for factories to produce aircraft. Initial work at Standiford Field, begun in June 1941, consisted of construction of runways, fencing, lighting, and drainage systems. Typically, a CAA project in the Louisville District consisted of construction of runways 150 feet wide and 3,900 feet long, with a limestone base and asphalt surface, together with auxiliary structures. Several of these airfields became the basis for large commercial airline operations after the war. The present terminal facilities at Standiford Field in Louisville evolved from such a beginning.

Early airfield construction activity for the Army Air Force in the district included Godman Field at Fort Knox and

Completed hangar for Air Corps operations, Godman Field, Fort Knox, Kentucky, 6 October 1941.

Bowman Field at Louisville. Originally used as a commercial airfield on the outskirts of Louisville, the Army Air Force took over Bowman Field in August 1940. The Louisville District constructed additional runways along with over 100 buildings allowing the field to serve as a supply depot, air crew and combat glider training base, and near the end of the war, as a convalescent hospital for wounded flyers. The Quartermaster Corps initiated work at Godman Field with Works Progress Administration (WPA) labor in 1940, and the district took over in 1941. It completed several runways 150 feet wide and 5,400 feet long for use by an observation squadron attached to the armor force at Fort Knox. In addition, it constructed a large aircraft hangar with observation tower that still serves certain base functions today.

The district's Navigation Branch administered the newly assigned military construction mission in the district until early 1942 when it set up a separate Military Branch to oversee the projects transferred from the Quartermaster Corps in 1941. The district carried out the transfer from the Quartermaster Corps rather smoothly; the general procedure was to appoint the former constructing quartermaster at the project location as area engineer. He reported to the district engineer.

The huge military mission meant substantial increases in personnel and adjustments in office space, requiring various district elements to relocate in buildings scattered throughout Louisville. As an indicator of rapid personnel turnover, by 1945 nearly 575 former district employees were serving in the armed forces, 5 of whom died while on active duty. The urgency of the military buildup required major reassignment of district personnel from civil works projects, resulting in their near suspension. In fact, in 1942 the only significant civil works activities under construction were flood protection projects at Paducah, Kentucky, and at Jeffersonville and Evansville, Indiana.

At each major project site, fiscal management was a prime concern with an internal organization set up to handle accounting. Project personnel reported to the Accounts and Audits Unit at the district office, and that unit prepared consolidated district fiscal reports. The scope of mission expansion reached nearly overwhelming proportions in 1942—the peak year for military construction in the district—when daily expenditures often exceeded $1 million, a figure nearly as much as the district had expended on civil works in an entire year prior to the start of flood control projects in the Ohio River basin. The district's accounts and audits unit prepared monthly cost analysis reports for the few civil works projects and for as many as 50 military projects.

The major mission of the Corps of Engineers in 1942 was in support of a national effort to train, house, and equip Army troops headed for the battlefields. Initially, the geographic boundary for military activity conformed closely to a district's civil works boundary, based on river drainage area. However, in late 1942 an administrative realignment was instituted to make Corps division military construction boundaries conform to Army Service Command boundaries. The Ohio River Division, which included the Louisville District, assumed construction responsibility for the Fifth Service Command headquartered in Columbus, Ohio. The Corps then transferred its division offices to that location. Army Service Commands generally followed state boundaries; therefore, the realignment meant a substantial increase in the geographic area of the Louisville District for military construction. The district took charge of certain airfield and ordnance plant

construction in Indiana while losing some projects in Illinois to the Chicago District. It did retain work at Chanute Field in Rantoul, Illinois.

In the early stages of the war, the Corps built many projects, particularly housing, according to standardized plans. However, each might have peculiar requirements for utilities placement. Generally, construction of military projects was initiated by a directive from the Office of the Chief of Engineers specifying the nature of work at a particular installation along with an allocation of funds. The Louisville District had a diversified military construction mission in World War II consisting chiefly of troop cantonment structures, munitions and ordnance plants, supply depots, airfields, hospitals, modification centers, and the renovation of buildings for special use.

In addition to airfield projects initiated in 1940 and 1941 for the CAA and Army Air Force, the district constructed and expanded additional airfields during World War II including two of particular note. In June 1942 construction began on the Air Force Advanced Twin Engine School at Seymour, Indiana. A massive venture, it consisted of construction of technical and operational buildings together with housing for a school of 380 officers, 475 cadets, 13 nurses, and 2,324 enlisted men. In addition, the district built Freeman Army Airfield, consisting of four runways and parking aprons and five auxiliary landing fields. The Corps completed the project within one year at a cost of $15 million. The Twin Engine School at Lawrenceville, Illinois, consisted of similar facilities, including George Army Airfield and three auxiliary fields. The Corps completed the project in late 1942 at a cost of around $10 million.

In addition, the Louisville District received several vast construction projects at Fort Knox and Camp Breckinridge, Kentucky, and Camp Atterbury and Fort Benjamin Harrison, Indiana, and continued work on various facilities at each of these installations throughout the war. The Corps added Camp Campbell, Kentucky, and Camp Thomas Scott at Fort Wayne, Indiana, to the Louisville District in late 1942. Initial mobilization construction at these bases involved the quick erection of frame barracks for troop housing, along with support facilities such as kitchens and mess halls, fire houses,

Additional housing for 1,325 enlisted soldiers, Camp Atterbury, Indiana, 14 November 1942.

roads, warehouses, utilities, fencing, motor vehicle storage and maintenance areas, and in some instances, field exercise training areas.

Through able administration of construction contracts, the number of structures at Fort Knox tripled by the end of 1942. In addition to the typical cantonment facilities described above, as late as June 1945 the district constructed a training area at Fort Knox known as "Little Tokyo." It duplicated structures normally found in a Japanese village in order to familiarize invasion troops with what to expect in the event of a landing.

The Corps designed Camp Atterbury near Indianapolis and Camp Breckinridge near Morganfield as motorized, triangular division cantonments. Construction of initial basic facilities at Camp Atterbury consisted of 520 mobilization-type buildings and a semipermanent hospital on about 40,000 acres of land to house a division of 35,816 enlisted men and 1,642 officers. One contractor designed the camp while five contractors constructed it. An area engineer with a 53-member staff supervised the work. The Inspector General's report in April 1942 noted that at Camp Atterbury, "Work in place was well performed and materials being used were in compliance with contract requirements. Buildings and other structures showed evidence of careful inspection."

Semipermanent hospital buildings in various stages of completion, Camp Atterbury, Indiana, 25 April 1942.

Following construction of essential structures and utilities at Camp Atterbury, additional projects there consisted of an airfield, a gunnery range, and the alteration of the base hospital to a general hospital complete with classrooms, housing, recreation facilities, and laboratories for medical staff. At Camp Breckinridge and other troop training bases, the district completed similar construction programs.

To properly equip and arm American troops, the Corps of Engineers constructed a number of ordnance and munitions plants, some on a "crash" basis in preparation for the invasions in Europe and the strikes on the Pacific islands. The hurried projects of 1941 and 1942 tapered off during the next two years, but in 1945, ammunition requirements exceeded production, and a resurgence of munitions plant construction occurred. From 1941 to 1945 the Louisville District supervised the construction at numerous such facilities, some covering vast acreages and requiring hundreds of buildings.

Significant projects included: the Ohio River Ordnance Works, Henderson, Kentucky; Hoosier Ordnance and Indiana Ordnance, Charlestown, Indiana; Evansville Ordnance Plant, Evansville, Indiana; Bluegrass Ordnance Depot, Richmond, Kentucky; Fall Creek Ordnance, Indianapolis, Indiana; Vigo Ordnance Plant and Terre Haute Ordnance Depot, Terre

Construction and alterations to existing Village Fighting Course, Easy Gap area, Fort Knox, Kentucky, 3 July 1945.

Haute, Indiana; and Kingsbury Ordnance near La Porte, Indiana. District personnel also oversaw construction of many related projects such as ordnance testing facilities at Jefferson Proving Ground near Madison, Indiana.

Several projects typify the general character and scope of the district's work at ordnance and munitions plants. Activity at the Ohio River Ordnance Works consisted of the design, engineering, construction, and preparation of production equipment for the manufacture of anhydrous ammonia on an 832-acre site. Construction began in late April 1941 and was completed in September 1942 ahead of schedule. The project was constructed within the original cost estimate in spite of inflationary rises in material costs, the added cost of increased security after the declaration of war, and extensive use of overtime charges. Buildings at the plant were of a temporary nature (five-year life). The plant had a production capacity of 150 tons of liquid anhydrous ammonia per day.

Indiana and Hoosier Ordnance Plants were located close to each other in Clark County along the Ohio River. Indiana Ordnance was a vast $75 million facility for the production of smokeless powder. The E.I. Dupont de Nemours Company constructed the plant in 1941 and placed it in operation in

early 1942. Said to be the largest powder-producing plant in the world, its six production lines each had a capacity of 100,000 pounds per day. The district built a variety of structures there, and in 1945 used German prisoners of war to construct a plant for the production of rocket powder. Also completed in 1942, Hoosier Ordnance was designed for loading artillery powder charges.

At Evansville, the ordnance project consisted of renovation of a Chrysler Corporation plant and construction of facilities for the production of .45-caliber ammunition. Vigo Ordnance, completed in 1942, supplied shell detonators and primers to the military. Fall Creek Ordnance produced armor plate. Another project exemplifying the diversity of the district's military mission was construction of the Jefferson Proving Ground. The proving ground tested ammunition, artillery, bomb components, and pyrotechnics.

Other important facilities in the military buildup included hospitals and associated structures. The Louisville District constructed several such large-scale projects. Work at Billings General Hospital at Fort Benjamin Harrison involved construction of a 1,060-bed hospital, a medical technician school, and a field hospital unit. Construction of the 70-building complex began in 1941 and was completed in November 1942 although it opened its doors for service in June. The district leased Darnell General Hospital at Danville from the Commonwealth of Kentucky and converted it to military use in 1942. The same year, the Corps built Nichols General Hospital at Louisville, a multistructure facility with a 1,000-bed capacity. It constructed buildings with a five-year life expectancy that were still in use in the late 1960s, although not by the district.

Although work at the munitions plants proceeded throughout the war, the military construction program of the district began to taper off in 1944–45. In 1944 the district centralized its military program to reduce administrative costs. It closed some of the area engineer offices at major projects and provided construction inspection to projects in Kentucky by mobile teams from the Louisville Office. An area engineer office at Columbus, Indiana, provided inspection teams to projects in that state.

By 1944, the Army Corps of Engineers had proven its construction and management expertise, leading General Eugene Reybold, Chief of Engineers, to declare that by 1943 the Corps "could move the Army and the Air Force any damn place there were Germans and Japs to destroy; whether it meant building a truck road around the Himalayan Hump, rebuilding wrecked ports of Italy, or ferrying heavy tanks across the flooded river. We were the men who could do it, because, by God, we were getting it done."

One special assignment illustrates the relentless pressures on the district in the construction program. On a Friday the district received notification that German prisoners would arrive in Indiana the following Tuesday, and that two internment camps had to be ready for occupancy by their arrival. Specifications for each camp called for tent platforms, mess halls, security fencing, water supply, and sewage facilities. Personnel worked long hours over the eventful weekend and completed the two camps within the 72-hour period.

During the war the district functioned in a near emergency status, led by aggressive and capable district engineers, Colonels Henry Hutchings, Jr., Henry F. Hannia, Jesse A. Veal, and Gilbert Van B. Wilkes. The district constructed mammoth works under orders which called for completion in 30, 60, or 90 days, and in the face of labor, material, and equipment shortages. The district workforce persevered, using available materials, employing large numbers of women to supplement the office staff, and even resorting to the use of prisoners of war to complement the labor force. With such constraints, the district accomplished the largest construction program in its history.

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Formation of the Manhattan Engineer District

by Janet A. McDonnell

One of the Corps of Engineers' greatest challenges and responsibilities during World War II was the creation of the Manhattan District and the supervision of the Manhattan Project, the federal government's program to develop an atomic bomb. In late 1938, German scientists discovered that the uranium atom could be split. Scientists who had come to this country to escape Nazi oppression knew of the German research and feared that Germany would create an atomic bomb. In 1939, Albert Einstein and two other scientists sent a letter to President Franklin D. Roosevelt (FDR) emphasizing the importance of atomic research.

On 28 June 1941, FDR established the Office of Scientific Research and Development to coordinate atomic research. By spring 1942, research indicated that an atomic bomb was possible. Scientists experimented with different methods of separating the fissionable uranium–235 isotope from the non-fissionable uranium–238. They also tried to create plutonium, a new element that could be substituted for U–235, by bombarding uranium with neutrons. Their methods, however, had not yet been tested outside the laboratory and none had yielded anything close to the amount needed to make bombs.

By June 1942, the bomb program was ready for expansion and FDR placed the Corps of Engineers in charge of constructing production facilities. On 17 June 1942, Chief of Engineers Major General Eugene Reybold summoned to Washington, DC, Colonel James C. Marshall, the experienced district engineer of the Syracuse District—known to his subordinates as "Gentleman Jim"—a polished officer who was firm yet tactful. After arriving in Washington the next day, Marshall reported to Major General Wilhelm Styer, the chief of staff to the commanding general of the War Department's Services of Supply, a major division newly created to oversee Army logistics. From Styer, Marshall learned that

Reybold had chosen him to establish a new engineer district and construct new manufacturing plants for atomic fission bombs at a cost of $90 million. The plant would be part of a project already in progress to develop atomic energy for military purposes. Thus the Army became directly involved in a project in which it had been playing a minor role in since 1939. The next day Marshall received more information from General Styer and Dr. Vannevar Bush who headed the Office of Scientific Research and Development.

Marshall's task was unprecedented: to take the project from the laboratory stage to the production stage with the establishment of large industrial plants. He immediately began conferring with people and organizing. He opened a temporary headquarters in the new War Department building and began lining up personnel, drawing some of his staff from Syracuse. The Syracuse District had recently completed the major part of its war construction program, so Marshall was able to bring with him a small nucleus of key personnel without delay. For example, he brought with him from the Syracuse District Virginia Olsson, who served as secretary to the new district throughout its history. He named as his deputy Lieutenant Colonel Kenneth D. Nichols, a 34-year-old West Pointer who had been area engineer at the Pennsylvania Ordnance Works.

Although the new district was technically in existence from the date of the selection of its district engineer, 18 June 1942, it was officially activated on 16 August 1942, under the authority of General Order 33 of the Office of the Chief of Engineers (OCE). General Order 33 created an engineer district without territorial limits, to be known as the Manhattan Engineer District (MED), to supervise projects assigned to it by the Chief of Engineers. Special Order 177, OCE, dated 13 August 1942, officially assigned Marshall as district engineer and Nichols as assistant district engineer.

Marshall decided to locate his new district headquarters in Manhattan, New York, close to the North Atlantic Division and the offices of the major contractor, Stone and Webster. The name "Manhattan" provided an effective cover for the district's sensitive work since engineer districts were traditionally named after their headquarters city. Unlike other districts, MED had no geographic boundaries and its area

spread from Berkeley to Boston. Colonel Marshall, who was the only district head with the authority of a division engineer, reported directly to the Chief of Engineers. Moreover, this special district retained its own Washington Liaison Office on the sixth floor of the new War Department building.

One of the new district's first tasks was to acquire an adequate supply of vital materials. This experimental project did not get the high priority ratings reserved for essential weapons. To avoid attracting undue attention to the project, the overall priority was kept on par with other war construction. Officials assigned the project an AA-3 priority in July 1942. Policymakers regarded the atomic bomb as a long shot, and they believed that putting too much emphasis on it at the expense of planes, cargo ships, and other programs competing for resources could jeopardize the war effort. Only essential weapons slated for early production could claim the AA-1 and AA-2 priorities. AA-3 was the highest possible rating for plant construction projects. Nichols and other MED officials were discouraged by the low rating.

By September 1942, when Brigadier General Leslie R. Groves, the deputy chief of the Construction Division, as-

General Leslie Groves reviews papers with his secretary Mrs. Jean O'Leary.

sumed administrative leadership of the Manhattan Project, it was evident that the AA-3 base rating Marshall had secured in July would not be adequate to insure the uninterrupted

development of the atomic program. So MED moved to acquire broad authority to issue an AAA priority whenever there was a need to break a bottleneck. War Production Board Chairman Donald Nelson agreed to give the new rating. On 26 September, MED received a blank check to assign the AAA priority.

MED continued to grapple with problems of shortages of essential items. Unable to acquire the large quantity of copper needed for separating U–235 from U–238, the Corps borrowed 14,700 tons of silver from the U.S. Treasury (over $300,000 million worth) as a substitute. When it returned the silver after the war, only 1/36th of one percent was missing. Meanwhile, Groves took steps to procure another vital supply—uranium ore. There was already a contract in place to purchase uranium ore from Edgar Sengier, head of Union Miniere. MED acquired from the Belgian Congo the company's reserve of ore that it had stockpiled on Staten Island in 1940. Nichols arranged to purchase not only the large supply of high grade ore on Staten Island but additional ore stored in the Belgian Congo.

While officials grappled with the problems of acquiring adequate authorities and supplies, in the summer of 1942 they also sought to acquire suitable sites for the project. Project leaders had approved the location of the proposed plutonium pilot plant in the Argonne Forest near Chicago and leased 1,000 acres from Cook County. In addition, the University of Chicago agreed to provide an additional acre on the campus for future construction of additional lab space. To administer site acquisitions and oversee construction activities, Colonel Marshall established the Chicago Area Engineer Office in August 1942 and named Captain James F. Grafton as area engineer.

On 1 July 1942, Colonels Marshall and Nichols and representatives of Stone and Webster and the Tennessee Valley Authority (TVA) began surveying possible sites in the Knoxville area for the main production plants. The site had to have a nearby source of large amounts of continuous electric power and large quantities of water for cooling and processing. It had to be close to railroad lines and have good access roads for the delivery of heavy construction materials and supplies. The area also had to be large enough to construct a town.

Despite some advances, in its early months the program floundered because it lacked well-organized dynamic leadership. On 17 June 1942, FDR approved proposals made by Vannevar Bush and James B. Conant that the Army assume overall direction of the atomic program and that the Joint Committee on New Weapons and Equipment (JNW) of the Joint Chiefs of Staff establish a special subcommittee to consider the military application of atomic energy. At a meeting in September 1942 between Bush, Styer, and Lieutenant General Brehon B. Somervell, commanding general in charge of Services of Supply, the decision was made that a policy committee would be formed to oversee the program and that an Army officer would be chosen to carry out the policies established by the committee.

To strengthen the military leadership of the project, Secretary of War Henry L. Stimson named Leslie R. Groves, who had supervised the construction of the Pentagon, to supervise Army activities relating to the development, manufacture, and use of the atomic bomb. At his own request, however, Groves did not take official charge of the project until 23 September, the day he was sworn in as brigadier general. As the deputy chief of the Engineer Construction Division, Groves had already spent much time advising Marshall in the selection of sites for the Manhattan District facilities. This hard-driving, confident officer was not always popular, but he was an effective administrator.

Groves was directed to operate closely with the Construction Division and other elements of OCE. He would have complete responsibility for administering the entire project and determining priorities, for the formation of a committee to formulate military policy governing the use of the project's output, and for procurement of the Tennessee site as the location for its major activities. He was also to make plans for the organization, construction, operation, and security of the project and to implement those plans after they had been approved.

The same day that Groves took charge, Secretary Stimson and Generals Marshall, Somervell, Styer, and others agreed to establish a small Military Policy Committee to formulate project policies on research, development, construction and

production, and strategic and tactical matters. The committee, acting through Groves, assumed virtually complete control over all aspects of the atomic energy program.

After his appointment on 23 September, Groves immediately left Washington, DC, for Knoxville, Tennessee, to survey proposed project sites. He and Marshall spent the day going over the proposed site, which was 16 miles long and 7 miles wide, until they were satisfied that it met their needs.

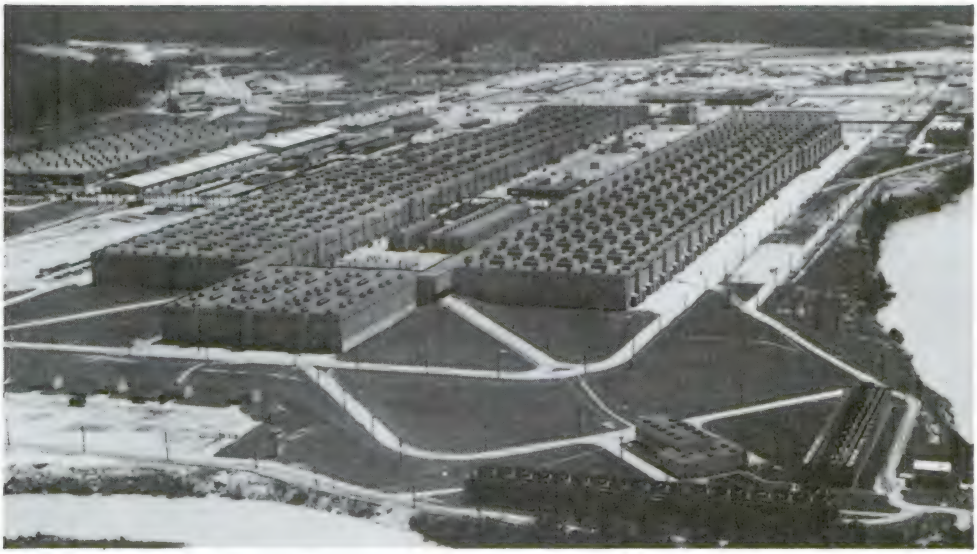
Groves and Marshall purchased 56,000 acres of rugged Appalachian terrain along the Clinch River in an area 12 miles west of Knoxville, near Clinton, Tennessee, for $3.5 million. The site provided water, power, transportation, the proper topography, and the isolation needed for security. Groves quickly began construction of the Clinton Engineer Works, and in a short time the Corps transformed this peaceful river valley into the bustling community of Oak Ridge.

One of the production areas at the Clinton Engineer Works, Oak Ridge, Tennessee, 1945.

Contractors provided the entire infrastructure of a city: roads, housing, schools, libraries, stores, churches, theaters, a police department, sewage system, and water supply. At its peak the Clinton works employed 47,000 workers, and by the end of the war, Oak Ridge would be the fifth largest city in Tennessee with a population of 75,000.

In addition, MED built the following production facilities at Oak Ridge to separate U–235 from U–238:

- An electromagnetic separations plant operated by Tennessee Eastman, a manufacturing subsidiary of Eastman Kodak ($300 million to build and $77 million to operate).
- A thermal diffusion plant ($10 million to build and $5 million to operate).
- A gaseous diffusion plant ($460 million to build).



Completed gaseous diffusion plant near Oak Ridge, Tennessee.

The Manhattan Project took a giant step forward in December 1942 when Italian Nobel laureate Enrico Fermi set off the first successful controlled chain reaction at the University of Chicago. He found that U–238 could capture neutrons and be transformed into plutonium. Soon after, Groves acquired 500,000 acres of land in south-central Washington near Bonneville Dam, which provided the water, electricity, and isolation needed for the construction and operation of plutonium reactors. Much like Oak Ridge, the Hanford Engineer Works required a large labor force (45,000 workers at one point), massive plants, housing, laboratories, test facilities, roads, and railroads. The Corps brought in machinery and materials from its other projects and recruited labor throughout the Northwest.

In the spring of 1943, the project entered a new phase with the establishment of a laboratory in the Southwest. The 38-year-old J. Robert Oppenheimer, a University of California physicist, had been directing the theoretical aspects of designing and building an atomic bomb. Oppenheimer and his associates concluded that their studies should be concentrated in one central laboratory devoted exclusively to that work in order to eliminate waste and duplication, permit freer exchange of ideas, and provide centralized direction for all the work. Groves appointed Oppenheimer to direct a new weapons laboratory at the site of the Los Alamos Ranch School for Boys in a remote part of New Mexico. Los Alamos became a tense, heavily guarded community of 7,000 people.

With the establishment of the Los Alamos facility on 1 April 1943, the basic structure of the Army's organization for administering the atomic bomb program was essentially completed. In the following months there were some administrative changes. For example, in mid-August MED moved from its temporary location in New York to permanent quarters at Oak Ridge, and Colonel Nichols, the deputy district engineer, replaced Colonel Marshall as district engineer. These changes, however, did not affect the basic structure of the Manhattan project.

The administrative elements that comprised the Manhattan Project were divided into two major categories: those that functioned as integral elements of MED and those that operated outside the MED structure, mostly in the area of high-level policy making or in executive direction of the atomic project. The central element in the high-level administrative hierarchy was Groves' personal headquarters, located in rooms adjacent to those already occupied by MED's Washington Liaison Office in the new War Department building. The Corps continued to assist the Manhattan Project, but the project functioned as a basically independent organization, with the project's commander (Groves) responsible to the Army Chief of Staff and the Secretary of War, and through them to the President. Groves, as officer in charge of the atomic bomb project for the Army, exercised command authority over MED, but he was not its chief executive officer. The district engineer held this position and reported to Groves. The district engineer presided over an organization that

was, as it emerged in mid-1943, similar to other Corps districts created for special purposes.

MED's administrative elements were grouped into two major categories: operating units, which were involved in the day-to-day monitoring of contractor operations; and staff units, which were engaged in overseeing and providing services. In both types of units, military personnel headed virtually all administrative elements down to the section level, although many MED employees who were in positions that required special knowledge or training were civil service workers. The chiefs of each of these units reported directly to the district engineer.

Operating units, each headed by a unit chief or an area engineer, were formed to monitor each of the major contractor-operated activities. In the early period of MED operation, the units conformed to the emphasis on construction activities, whereas later they reflected the shift to plant-operating activities. By the time MED headquarters moved from New York to Oak Ridge in August 1943, five major operating units had been established: Madison Square Area, Hanford Engineer Works, Clinton Engineer Works, New York Area, and Special Products.

The staff units concerned with overseeing project operations and providing services were divided into four categories: Unit Chiefs, Technical Division, Service and Control Division, and Administrative Division. The four unit chiefs, Y–12 (electromagnetic), K–25 (gaseous diffusion), X–10 (plutonium), and P–9 (heavy water), were responsible for the overall supervision of the construction and operations phases of the production process.

Despite the carefully crafted organizational structure, problems such as shortages of materials and labor, electrical failures, mechanical breakdowns, and low morale continued to plague the Manhattan Project. As the months passed, the sense of urgency and the pressure for success intensified. By spring 1945 the plants had produced enough material for a bomb. Before dawn on 16 July 1945, plutonium was detonated from a 100-foot steel tower in a barren desert area in southern New Mexico aptly named Jornada del Muerto (Journey of Death). The explosion, with the force of 20,000 tons of TNT, set off a huge fireball that rose slowly to 10,000 feet and

left a crater 1,200 feet deep filled with pulverized dirt. The steel tower evaporated; radioactive material was deposited 120 miles away.

Thus, the Corps of Engineers successfully completed one of the most challenging and unique construction projects of the war. The Corps rapidly converted its peacetime rivers and harbors organization to war activity; coordinated construction with research, created a livable environment for employees and their families, and coordinated the work of hundreds of contractors. Perhaps as impressive as the scope of the project was the patriotism demonstrated by civilians and soldiers alike who worked long hours under uncomfortable and often hazardous conditions. Although conflicts occasionally arose between scientists and officers, generally both groups approached the project with a true cooperative spirit.

Sources for Further Reading

The best sources dealing specifically with the Army engineers' role in the development of the atomic bomb are Vincent C. Jones, *Manhattan: The Army and the Atomic Bomb Project* (Washington, DC: Center of Military History, U.S. Army, 1985) and Lenore Fine and Jesse A. Remington, *United States Army in World War II. The Technical Services. The Corps of Engineers: Construction in the United States* (Washington, DC: Office of the Chief of Military History, U.S. Army, 1972).

A good source on the Manhattan Project in general is Stephane Groueff, *The Manhattan Project: The Untold Story of the Making of the Atomic Bomb* (Boston: Little, Brown, and Company, 1967).

For valuable accounts by actual participants in the project, see Leslie R. Groves, *Now It Can Be Told: The Story of the Manhattan Project* (New York: Harper and Brothers, 1962) and K. D. Nichols, *The Road to Trinity* (New York: William Morrow and Company, Inc., 1987).

SECTION III

Research and Development

In the conduct of war, nations must depend on effective equipment as well as the individual soldiers and their superior training in order to win. Without effective equipment, the chances of success for the soldier are small. The sound research and development program developed by the Engineer Board prior to World War II allowed the Corps of Engineers to expand its existing research and development program to the point where it produced enough equipment in sufficient time to contribute to winning the war.

On 14 September 1921, the Chief of Engineers established a Board on Engineer Equipment at Camp A.A. Humphreys (later Fort Belvoir). It had the responsibility for designing, testing, and adopting articles of engineer equipment for use by the Corps. During its 11 years of operation, the Board on Engineer Equipment conducted work on 349 projects.

On 26 January 1933, a new Army regulation established an Engineer Board and required it to develop Engineer equipment, consider subjects pertaining to the Corps of Engineers as referred by the Chief of Engineers, and originate and submit to the Chief of Engineers recommendations to improve the Corps of Engineers.

From January 1933 to June 1945, the board worked on 1,663 projects, 87 percent of which began after 1 July 1940. The Corps of Engineers Technical Committee recommended 885 items of equipment for adoption as standard, standard substitute, or limited standard during that period.

There were 14 fields of engineer research and development. Listed alphabetically they began with Air Corps installations; barrage balloons; bridging (one of the more important fields of engineer research and development); camouflage materials; demolitions and obstacles; electrical and related work; and electronics, including research on mine detection equipment.

In addition to its work in specific fields of research and development, the Corps of Engineers pursued investigations into general fields. One field included lightweight equipment, transportable in the C-47 cargo plane, for airborne engineers in the construction and repair of airfields.

The War Department assigned the Corps of Engineers the responsibility for the compilation and reproduction of all maps for the Army ground forces. The Engineer Board designed a complete mobile map reproduction train which consisted of ten truck-mounted units and provided for both lithographic and photographic duplication for field mapping units.

The mechanical equipment field included the tractor-mounted earth auger (requested by the Chief Signal Officer in March 1944), a medium and light portable sawmill, snow removal equipment designed for use at military airports, railroad track-laying machinery, portable gasoline power tools, air compressors, sprayers, power shovels, pile drivers, cranes, tractors, dozers, and fire-fighting equipment.

In the field of petroleum distribution equipment, the Army initiated large-scale procurement of pipeline equipment about a year after the United States entered the war. Until that time the Army relied upon tank cars and trucks for the distribution of petroleum products.

One field of responsibility belonging to the Engineer Board, that of water supply equipment, required that safe, potable water be provided for troops, either by purification or distillation. The board later developed new, lightweight equipment to be carried by troops.

The following essays discuss just a few of the many projects of concern to the Engineer Board during World War II.

Probing for mines proved dangerous and tedious. In search of a better way, the Engineer Board instituted research on mine detection equipment, both metallic and nonmetallic, early in the war. The development of the mine detector is the subject of the first essay.

The second essay describes the development of the tank dozer. Initially, experiments conducted on clearing mines consisted of detonating them with explosive devices. But the board heard about British efforts to clear minefields by using a dozer blade on a tank, and it began experiments that led to the successful development of the tank dozer.

The use of heavier mechanized equipment by the military led the board to develop new types of bridging equipment. The third essay concerns the development of the all-purpose Bailey bridge.

The development of airfields for tactical aircraft and heavy bombers brought a corresponding requirement for the development of landing mats and landing fields to support them. These are the subjects of the last two essays in this section.

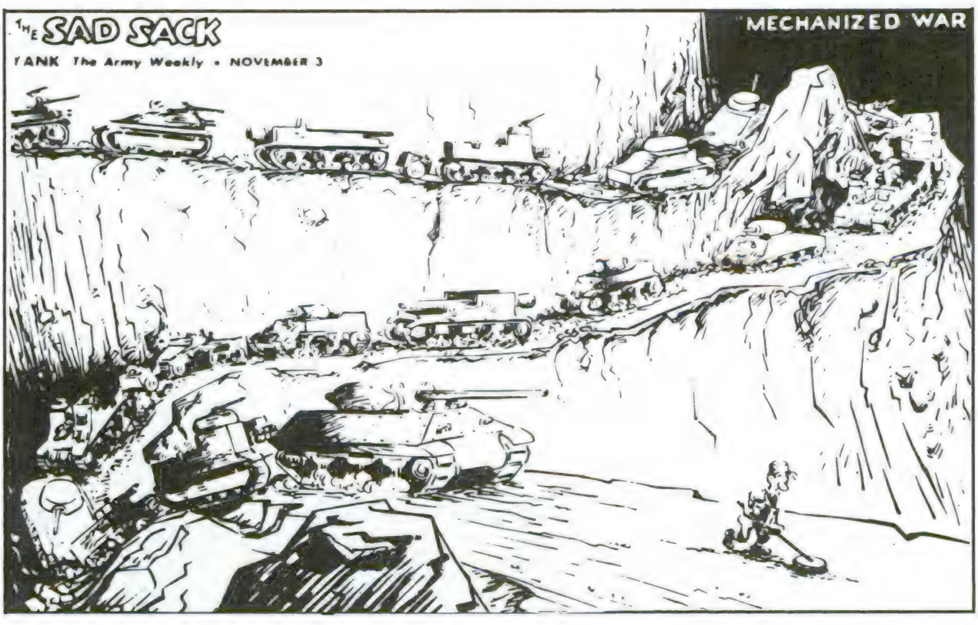
These essays give some idea of the Engineer Board's wide-ranging effort during World War II to provide the soldiers with the best equipment to perform their missions.

The Portable SCR-625 Mine Detector

by Frank N. Schubert

In February 1942, less than three months after the United States entered World War II, the Army completed a long development process and stood ready to begin production of a small but important piece of equipment, the SCR-625 mine detector. The Army had known that it needed a detector long before the United States became involved in the war. Early interest dated back to studies of the effectiveness of various artificial obstacles in 1937 and 1938. In those years, engineer troops had run tests comparing land mines, antitank ditches, wooden piling, wire rolls, and road craters. The experiments had shown that all of the obstacles would be effective if properly placed and led to further research at the Engineer School.

These assessments were carried out for the Engineer Board, a small organization housed in a World War I barracks at Fort Belvoir, Virginia. The seven-member board, managed on a daily basis during the prewar years by its executive officer, Captain James M. Young, was the research



and development arm of the Corps of Engineers. Despite the large mission, which involved considering and evaluating possible changes in engineer equipment, the board was a low-budget operation. In 1939, it had only 40 civilian employees to go with its handful of officers and a budget of $100,000. The small size of the enterprise allowed for little specialization. Captain Young himself, while seeing to the daily operation of the board, worked on projects involving bridging, construction machinery, and demolitions. The board was a field agency of the Office of the Chief of Engineers and reported to the chief through the Military Division of his headquarters.

While still operating in this framework of very meager support, the board reached its basic prewar conclusions about the utility of mines. These conclusions held that antitank mines alone could be singularly effective obstacles, with other types of obstacles augmenting them as needed. With or without supporting systems, the mines were devastating as well as easily transported, emplaced, and hidden.

The emphasis on the value of mines as obstacles led eventually to investigations of possible ways to either destroy or remove them. Technical responsibilities for mines rested with the Chief of Ordnance, but the mission of detection belonged to the Corps of Engineers. So, in April 1940, the Office of the Chief of Engineers ordered the Engineer Board to study detection and neutralization. The project got under way in earnest in the fall of 1940.

All of the mines that were known to exist in 1940 were encased in metal. This characteristic simplified development of a mechanism to signal the presence of these hidden underground explosives. On 3 September 1940, the engineers asked for help in developing a metallic mine detector from the recently organized National Defense Research Committee. The specifications required that the instrument be able to detect a steel plate 1/8-inch thick and 10 inches square that was buried as deep as 18 inches below the surface. At the same time the detector had to be able to discriminate between mines and small bits of metal, such as the nails in an operator's shoes.

The National Defense Research Committee, established in June 1940 by order of the Council of National Defense,

was the brainchild of Dr. Vannevar Bush. It coordinated and supported scientific research on military equipment. The committee supplemented the experimental and research efforts of the War and Navy Departments, including the Corps of Engineers, and also undertook its own projects. It had no laboratories of its own and assigned projects to existing government laboratories, the National Academy of Science in conjunction with the National Research Council, academic institutions with research facilities, and industrial research laboratories. The National Defense Research Committee's successor, the Office of Scientific Research and Development, established by an executive order in June 1941, served as a center for the mobilization of scientific personnel and resources for defense purposes. Most of the research done under its auspices came at the request of the Army or Navy.

For most of 1941, the Engineer Board and the National Defense Research Committee sponsored parallel investigations. Captain George A. Rote of the Corps of Engineers supervised the research for the board. Essentially his project, numbered SF 316 by the board, looked for a device similar to the commercial treasure-hunting detectors then on the market, with the additional possibility of mounting it on the front of armored vehicles to warn them to stop before hitting a mine.

Rote purchased examples of the seven most promising commercial detectors. All of these worked on the basis of radio frequencies. Two transmitters emitted radio beams that canceled each other out except when a metal object got in the way. A receiver detected the changing sound. One product in particular interested Rote. It worked on an audio frequency, with the increased volume of the 1,000-cycle note in the resonator showing the presence of metal. He found this model, manufactured by Hedden Metal Locators, Inc., of Miami, Florida, especially appealing because it was light and had about the degree of sensitivity needed. By the summer of 1941, Rote chose the Hedden model as the basis for further development.

Meanwhile, the National Defense Research Committee contracted with the Hazeltine Service Corporation of New York for the purchase of its detector. The Hazeltine model, which was delivered to Fort Belvoir on 1 August, was

heavier and bulkier than the Hedden detector, but Hedden lacked the facilities to make refinements in the instrument for military use. Hazeltine, on the other hand, was well equipped to modify the Hedden-type detector and was awarded the production contract for the SCR–625, which was dubbed "the Hedden–Engineer Board–Hazeltine mine detector" by the authors of the official Army history, *The Corps of Engineers: Troops and Equipment.*

The most prominent feature of the instrument that emerged from this collaboration was the 6-foot exploring rod which the operator held. At the end of the rod was a pie-

An instructor in the Engineer Mine School demonstrates a mine detector to soldiers of the 81st Engineer Combat Battalion, Honsfeld, Belgium, March 1945.

shaped search coil mounted under a wooden disk that was 18 inches in diameter. Strapped to the operator's side in a canvas haversack were the dry-cell batteries that induced a magnetic field around the search plate and amplifier. The resonator was attached to the operator's shoulder. A set of earphones completed the instrument. The entire detector set weighed 7.5 pounds and produced a low hum in the operator's earphones. The SCR–625 discerned metallic mines 6 to 12 inches below the surface, rather than the desired 18 inches, but was acceptable because few mines were ever buried more

than 12 inches below ground. It had two serious shortcomings: it was not waterproof and it was quite fragile.

By February 1942, just weeks after American entry in the war, the engineers were in position to standardize this set. The timing was fortunate. That summer, operations of the British Eighth Army in North Africa, in the campaign that ultimately drove the Germans from the Egyptian border across Libya and toward Tunisia, provided the first operational test for the SCR–625. The detector was standardized and put into production by the Army's Services of Supply in September 1942 and was available for the American units that landed in Morocco in November.

Overall, the new detector performed well and became one of the most popular pieces of Army equipment in North Africa. Mines played important parts in the highly mobile campaigns along the coastal plain and adjacent desert as each side sought to channel or impede the movements of the other. Engineer units in North Africa spent as much as half of their time laying mines or lifting and clearing them. Often engineer troops had to probe for them slowly and tediously and at great personal risk with bayonets. The detectors proved safer and more reliable than the bayonets and even surpassed "scorpions"—flailing chains attached to drums that were pushed by tanks and detonated mines that they contacted. Moreover, the supply system worked well enough that detectors generally were sufficiently plentiful for use in clearing long stretches of road, bivouac areas, and airfield sites. They, along with bayonets and a keen and wary gaze, represented the engineer's primary tools for removing mines in North Africa.

Ralph Ingersoll, a journalist and editor who accompanied engineer troops of the 1st Infantry Division in Tunisia, watched many times as soldiers clearing a road walked forward and swung their detectors—sometimes known as outdoor carpet sweepers—slowly from side to side, as if "sweeping with a broom held at arm's length." The detector swept a band 3 to 4 feet wide. In the presence of metal buried less than 12 inches below the surface, the hum produced by the magnetic field increased in pitch. With the search plate directly over a mine, the sound became so high and strong that it was almost a shriek. The deflection of the needle on

the meter in the control box at the operator's side also showed the presence of the mine.

When the operator detected a mine, he did not stop to disarm it. He pointed it out to another man following him, who marked the spot. Others came behind them, cautiously unearthed the device, and deactivated it. In his book, *The Battle is the Pay-off,* Ingersoll called the method "simple and foolproof," and boasted that the 1st Engineer Combat Battalion, "which has probably removed more enemy mines than any other single engineer battalion at the front, has not had a single casualty in the process."

The SCR–625 did indeed perform well in North Africa, but proved less reliable during the Italian campaign later in 1943. There were several reasons that such a useful piece of equipment so quickly became inadequate. First of all, the soil in Italy contained substantial amounts of iron ore, which the detector was unable to distinguish from metallic mines. In addition, the Germans responded to Allied success with the SCR–625 by lessening their dependence on metallic mines. Instead they used ever-increasing quantities of nonmetallic Schu antipersonnel mines, which were assembled in wooden boxes. The Germans had used these mines in North Africa, but in such small numbers that they were not a serious problem.

The defects that came to light in Italy underscored other shortcomings as well. Operators tired quickly because of the 7.5-pound weight of the instrument. Moreover, even though the SCR–625 was not used while under enemy small arms fire, soldiers still disliked having to stand upright while using it. Besides, the sets did break down, especially in the rain. So, while it may have been true, as the authors of *The Corps of Engineers: Troops and Equipment* claimed, that "the development of the portable mine detector was the outstanding contribution to the passage of artificial obstacles. . ." during the so-called defense period between the start of American preparation for war and the first movement of our troops overseas, the detector was far from perfect.

Once these defects became known, the Engineer Board team that worked under Rote, promoted by 1944 to major, went in several directions seeking improvements. The program of development changed constantly as the enemy

introduced new mines that were lighter and used less metal. Rote worked on a vehicle-mounted detector and experimented with devices that would detect nonmetallic mines, both in combination with a metallic detector and alone. His team also wanted to develop a detector with a shortened arm, so soldiers would not be as exposed while using it.

The modification of the SCR–625 to make it lighter, more rugged, and more resistant to water did solve some of the problems. The coils were compressed lightly into grooves between light and strong balsa wood disks that protected the coils from damage and water. The balsa was also a relatively poor conductor of heat and reduced the susceptibility of the instrument to changes in temperature. Rubber rings, 1/2-inch wide, were added to support the coils, allowing them to resume normal positions after expansion.

A new model, known as the Short-Arm Detector Set, SCR–625 (H), was designed and authorized for procurement at the start of 1945. This modification retained the original

The Short-Arm Detector Set, SCR-625(H).

standard of performance but incorporated two significant changes. At 3.5 pounds, this model weighed less than half as much as the original. A soldier could use the new version while kneeling or prone. The short-arm detector was developed after tests of commercial equipment and improvements that took over one year. However, the project moved quickly once basic decisions were made about the basic approach to be taken. Four months of development and testing culminated in the issue of specifications by the end of October 1944 and the start of procurement in January. The new instrument, which was not introduced in time to be used in the European theater of operations, would have enabled a soldier to

feel for trip wires with one hand while sweeping for mines with the other. Also, with a kit, it was convertible in the field to the original size for use in an upright position. Although Rote's team never developed a suitable detector for nonmetallic mines before the end of the war, their ongoing research did bring the unit cost of the SCR–625 down from $820 to $491.

The engineer research program did not produce the perfect detector, but late in the war, during the battle for Europe, the SCR–625 still retained some usefulness for troops sweeping roads for metal antitank mines. Soldiers on the western front during the advance across France into Germany in 1944–45 did not encounter the same ore-rich soil that had caused problems in Italy, but many of the roads were littered

Soldiers of the 308th Engineer Combat Battalion minesweep a snowy road in Belgium, 6 January 1945 (left: Corporal Joseph Denucchi; right: Private First Class Dennis Lulowski).

with shrapnel, which caused the same problems as buried ore. The "manhole covers on a stick," as a New York *Times* reporter called them, picked up everything, while bayonets frequently prodded for mines that were just not there.

Still, the 105th Engineer Combat Battalion of the 30th Infantry Division relied extensively on the original instrument on the campaign across France and into Germany. One day of August 1944, a company of the battalion removed

The Tank Dozer

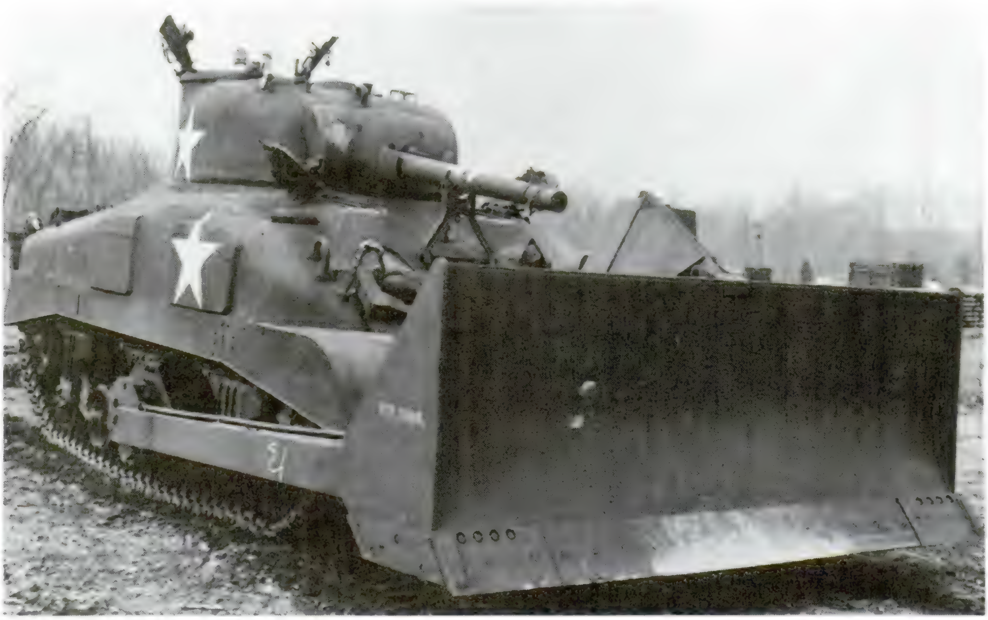
by Martin K. Gordon

Land mines had replaced natural barriers as the most serious threat to the advance of mechanized forces by 1940. The ease of transporting, placing, and concealing mines established their effectiveness, especially in mobile situations. As a result, at the beginning of World War II the Engineer Board focused its attention on detection rather than clearing or removing those threats to life and vehicles. The Engineer Board was a field agency of the Military Division of the Office of the Chief of Engineers. Its function was to examine engineer equipment critically and conduct research and experiments in order to improve the tools and machinery in the hands of engineer troops.

By the early months of 1942, techniques for detecting mines had advanced far ahead of methods for their removal. The use of explosives to detonate the mines was then the recommended manner of removal. Following the British example, early research centered on the bangalore torpedo, an explosive-filled metal tube that was pushed into a minefield and exploded, setting off nearby mines. But the torpedo did not meet the need for a means of removing several mines without exposing the troops either to covering fire or to the mines themselves.

Both the engineers and the Army Ordnance Department explored mobile, mechanical, and explosive methods of mine clearance. The engineers at first concentrated on explosive means for clearing minefields while the ordnance specialists investigated mechanical means. But, according to an official history of that project, "The best that could be said for the various appendages developed by the Ordnance Department for tanks—disk rollers, drums, drag weights, and a flail device modeled on the British scorpion—was that some showed promise."

Meanwhile, in October 1941 the Engineer Board learned of the British use of dozer blades on tanks in North Africa. That suggested the possibility of excavating mines instead



The tank dozer could plow a path through dragon's teeth and antipersonnel obstacles found on invasion beaches.

of exploding them. In January 1942, First Lieutenant George M. Hays of the Coast Artillery School formally recommended to the Adjutant General's Office the mounting of a bulldozer blade on a tank. The advantages were significant—rapid operation by a small crew with gun protection. A tank so equipped could shunt surface mines to the side and excavate buried mines without detonating them. The Adjutant General's staff passed the idea on to the armored force. Its research board felt that mine clearing was an engineer function and forwarded the recommendation to the Corps of Engineers. There it came to the Engineer Board.

But Major Karl F. Eklund, who supervised the Mechanical Equipment Section at the Engineer Board, believed the tank dozer would be a long time in the making if it could be developed at all. He knew that the Desert Warfare Center had abandoned experiments mounting V-shaped blades on tanks for road construction work. Instead, by August 1942, the center had recommended tractors. The basic tank dozer idea had so much merit, however, that Major Eklund and others at the board recommended a dual approach. They felt that a tank-mounted dozer blade might solve the mine

clearance problem, but that it was not the best option for overcoming ditches, craters, and other antitank obstacles. The British, whose bulldozer operators already had worked under fire, had embarked upon a program to produce armored tractors. Based on that example, the board requested authorization to develop armored tractors at the same time it was collaborating with ordnance researchers on the development of the tank dozer.

In June 1942, General Brehon S. Somervell's Services of Supply (SOS) disapproved the request because of the scarcity of steel plate and the feeling that the research on the tank dozer might be adequate for both projects. SOS did authorize collaboration between engineer and ordnance researchers on developing a bulldozer attachment for tanks. Up to that time no agency had conducted practical tests with a tank using a dozer blade to clear mines.

Although SOS in June 1943 had directed the Ordnance Department to assume all responsibility for development of the tank dozer and to receive all funding for the project, Eklund continued with the project. Funds came from the Engineer Board's project for the clearance of beach and underwater obstacles. Eklund believed that combat engineers needed a tank dozer to overcome obstacles other than mines, and that he was on the verge of developing such a vehicle.

Working with the Caterpillar Tractor Company and two industrial producers of tractor blades, the LeTourneau and LaPlante–Choate Companies, Eklund and the board's project engineer, William J. Murwin, experimented with mounting various blades on tanks. The board's researchers concentrated on developing the best possible blade for mine removal. But trying for an even more useful piece of equipment, they felt that a blade capable of removing mines might also be useful in other clearing operations.

Eklund talked each company into constructing two pilot models, each with a different style blade, at no expense to the government. The board and the companies tried several variations of weight, height, teeth, hydraulic and cable controls, designs to control the blade's rising out of the ground, and other features. The project's high standards required that the tank dozer be as easy to control as a bulldozer. Eklund conducted experiments at Fort Pierce, Florida's beach obstacle

course; at Fort Knox, Kentucky, with the armored forces; and at other installations. The June 1943 Fort Pierce tests of the LeTourneau and LaPlante–Choate blades were successful. The tank dozer was now a reality. Meanwhile, ordnance researchers continued experimentation on a blade suitable for light tanks to use in the Pacific's jungle warfare.

Both tank dozer blades were then approved and purchased for the Army's medium Sherman tanks as what was officially named the "bulldozer, tank mounting for M4A1, M4A2, M4A3 tanks." The LeTourneau blade was cable operated and the LaPlante–Choate system used a hydraulically-operated blade. By September 1943 all levels of the Army accepted the usefulness of the new blades, which operated from the tank's internal power supply and which the driver could jettison within ten seconds in case of emergency. Large-scale production of the dozer package began in December 1943 and the first units arrived in Italy in time for the spring 1944 Allied offensive.

As General Dwight D. Eisenhower noted in his autobiography, "A new piece of equipment that we began receiving about this time was a godsend to us. It was the 'tank-dozer.'" The Germans Eisenhower was facing were careful to destroy the bridges, culverts, and mountainside shelf roads that the Allies needed in their advance up the Italian peninsula, and they then used light-caliber weapons to stop the men and bulldozers sent forward to restore the roads. With more on his mind than stateside engineer research, Eisenhower devised a unique explanation of the origins of the tank dozer as:

> Some imaginative and sensible man on the home front, hearing of this difficulty, solved the problem by merely converting a number of Sherman tanks into bulldozers. These tanks were impervious to all types of small-arms fire. . . . From that time on our engineering detachments on the front lines began to enjoy a degree of safety that actually led them to seek this kind of adventurous work. None of us could identify the individual responsible for developing this piece of equipment but had he been present he would have, by acclamation, received all the medals we could have pinned on him.

If only Major Eklund had known of those sentiments!

Only on 5, 6, or 7 June would the engineers have enough daylight to complete their work before the tide rose.

Combined Army–Navy assault boat teams of 35 to 40 men would land three minutes behind the first units on OMAHA Beach. The sailors would work seaward destroying obstacles, while the soldiers cleared landward mines and barriers. The men would come from engineer combat battalions, special brigades, and Navy combat demolition units. Each assault team had a tank dozer. An Army–Navy support team followed every two assault teams. The teams at UTAH Beach had a slightly different organization which included the use of Army engineers against the seaward obstacles. Engineers for the OMAHA assault teams came from the 146th and 299th Engineer Combat Battalions. The UTAH assault teams came from the 237th Engineer Combat Battalion.

According to the plans, the demolition teams with their tank dozers would have just under 30 minutes to open gaps in the beach water barriers before the main body of infantry landed. In the attack on D-day, 6 June 1944, the tank dozers offered little help to the badly-mauled and frustrated teams. At OMAHA Beach, only 6 of the 16 M–4 tanks equipped with the special blades made it ashore, and enemy fire soon disabled 5 of them. However, the surviving tank dozer allowed the engineers to stop blowing up the obstacles, which sent metal shards over the increasingly crowded beaches. Instead, the assault teams removed the mines from the stakes, ramps, hedgehogs, and other barriers by hand, and let the tank dozer push the obstacles out of the way. Armored bulldozers later also helped remove the barriers. Clearing the obstacles on UTAH Beach was a much simpler operation. Although the engineers used two tank dozers, they mainly used hand-placed charges connected with primacord.

After breaking out of the beachhead in July, the Allied armies had to conquer the terrain as much as the enemy. With the exception of the Caen–Falaise plain, the Allies encountered the hedgerow, a traditional Norman farmer's means of enclosing his plots of land. The hedgerow was a fence, half earth, half hedge. Its dirt base varied from 1 to 4 feet thick and its height from 3 to 12 feet. Various brambles, vines, trees, and other vegetation then formed a hedge growing out of that earth parapet. Roads among the hedgerows

The tank dozer smooths the way as soldiers of Company C, 23d Armored Engineer Battalion, demonstrate obstacle breaching techniques on the Sigfried Line, 1944.

were often little more than narrow sunken lanes, ideal defensive sites. The Allied attack halted until those barriers could be opened.

The Allies discovered that tank dozers could breach about half of the dikes which the hedgerows formed. The dozers proved so popular that there was a shortage of them in Normandy. Ordnance detachments converted ordinary Sherman tanks into tank dozers in the field. But because breaching the hedgerows with tank dozers was slow, ordnance and armored units both experimented with different kinds of blades which would enable tanks to cut through the hedgerows quickly without preparatory demolitions or converting tanks to dozers. With the tank dozers and additional tanks equipped with special teeth to allow them to push through the hedgerows and not ride over them, the Allied advance resumed.

In the breakout from Normandy, tank dozers were often used to push aside rubble in the way of the armored forces. The engineers removed mines by hand. For example, as the 4th Armored Division began its movement later in July towards Coutances, it encountered a dense minefield. The advance halted for three hours while tank dozers constructed bypasses and the 24th Armored Engineer Battalion removed mines from the main road.

In the fall of 1944, the XX Corps of Lieutenant General George S. Patton's Third Army attempted to use the tank dozer in an assault on Fort Driant, the most important part of the modern defenses of the city of Metz. The fort's position on a dominant height enabled it to direct artillery fire along the axis of the Moselle River while guarding the southern approaches to Metz. Air and artillery bombardment failed to reduce the fort, so an infantry assault became necessary. Tank dozers were to fill the moat in front of the fort even though they were under enemy fire. Other tanks were to push snakes—long metal tubes filled with explosives—against the barbed wire and minefields to blow holes in them. The main attack came the morning of 3 October. The assault failed. The tank dozers broke down with mechanical problems and the snakes broke, making them incapable of being pushed into place. Infantry and tanks managed to push their way through another sector of the defenses, only to be ultimately repulsed.

In Germany, another effort to use the tank dozer as an armored bulldozer also failed. North of Aachen, the Wurm River protected Siegfried Line pillboxes from the advancing 30th Infantry and 2d Armored Divisions. The Wurm, about 30 feet wide and 3 feet deep, was easily forded; but its steep marshy banks were a real obstacle to tanks. The 30th Division's 105th Engineer Combat Battalion built ingenious tank bridges for the 2 October crossing. It used 30-inch steel pipe reinforced on the inside with smaller pipe and on the outside with a layer of cable-bound 6-inch logs. To protect the soldiers, a tank was to pull a sled loaded with five culverts to the river bank. A following tank dozer would then push the culverts into place on the soft banks and river bottom and cover them with dirt. Rainy weather, however, foiled the plans of the 105th. The tanks, the tank dozers, the culverts, the additional tanks sent to pull out the first tanks, and the tank dozers all became mired in the muddy banks. Finally, the engineers had to construct treadway bridges to enable the tanks to cross the river. Even then, tanks across the first bridge became stuck in the mud on the German side and were unable to reinforce the infantry.

The development of a piece of vital engineer equipment, the dozer blade, demonstrated the interaction of field needs,

engineer research and development, and field expediency. Yet, even though the tank dozer was used in several practical but unanticipated ways, it did not replace the individual combat engineer removing mines one at a time. Used to extinguish fires and employed in combat construction—much like an armored bulldozer—and in combat itself, mine clearance was only one accomplishment of the tank dozer.

It was out of those experiments for the assault on the Normandy defenses and the forthcoming battle for France that the need for an engineer armored vehicle was first defined. Engineers would need that vehicle for barrier penetration while under fire. The Engineer Board's study of British war operations against the Germans, its concern for providing all necessary tools and equipment to the combat engineers, and its thorough testing and development led to the tank dozer.

The dozer package proved a useful aid to our advancing forces in the European theater of operations where the enemy made use of the terrain. This armored vehicle with engineer capabilities was a necessity of modern warfare.

Sources for Further Reading

Information about the tank dozer, its design and use in combat, is available from various sources in small increments. Some of the better sources include: *Frank S. Beeson, Jr.*, an oral history interview by Lawrence Suid (Washington, DC, 24 September 1980); Blanche D. Coll, *et al.*, *Troops and Equipment. United States Army in World War II: The Technical Services, The Corps of Engineers* series (Washington, DC: Office of the Chief of Military History, 1958); Gordon A. Harrison, *Cross Channel Attack. United States Army in World War II: The European Theater of Operations* series (Washington, DC: Office of the Chief of Military History, 1951); Martin Blumenson, *Breakout and Pursuit. United States Army in World War II: The European Theater of Operations* series (Washington, DC: Office of the Chief of Military History, 1984).

The engineers decided that in designing and producing a new bridge they had the opportunity to correct many of the problems which had plagued similar projects in the past. To this end, they developed a set of criteria for the new bridge. First, the girder and deck system had to be capable of being strengthened at will and in place. This would allow flexibility in handling various vehicles. Second, all parts had to be made of readily available materials. Special steels were sometimes impossible to acquire during the war. Third, any engineering firm had to be capable of building the bridge. In the past some of the designs were so complex that only a few companies were able to produce the material. Similarly, close manufacturing tolerances would be avoided if possible. This would also simplify production by a variety of companies.

British floating Bailey bridge on Mark VI pontons. (Engineer School Library)

The engineers considered the realities of field use as well. They wanted the bridge to be transportable in the standard 3-ton lorry. Special purpose transportation vehicles compounded the problem of movement, maintenance, and supply. To eliminate the need for construction cranes and hoists, no part of the bridge would be heavier than a six-man load. In order to facilitate launching, the designers specified that the underside of the girders were to be kept smooth. A smooth under surface would also allow engineers to use the Bailey on pontons.

The bridge that finally emerged met virtually all of the designers' specifications. The central piece of the bridge was the Bailey panel. This was a welded truss, with vertical and diagonal supports, 10 feet long by 5 feet high. Each panel weighed 600 pounds. Panels were attached end to end with pins creating a multiple truss girder. The panels could be stacked three high and placed side by side. This resulted in such variations as the double-double Bailey (two panels side by side and two panels high) and the double-triple Bailey (two panels wide and three panels high). This meant that bridge components could be added to increase the load capacity of the bridge. For example, a single-single Bailey spanning 100 feet could support a 10-ton load. A double-single across the same span could support 28 tons. A 100-foot triple-single bridge could handle 45 tons, and a similar span double-double Bailey could support loads safely at 75 tons. In addition, the panels saved up to 40 percent in transportation space, were easy to handle, provided flexibility in construction, and were adaptable to float bridges.

The floor system of the Bailey was conventional. It consisted of floor beams placed at 5-foot intervals, with steel stringers, wood flooring, and wood ribands (curves). In time, steel ribands replaced the wooden material because tank tracks damaged the wooden components. The floor beams or transoms could be doubled, giving reinforcement to the floor. This also allowed construction of a two-lane bridge where the center girder was larger than those on the outside of the traffic lanes.

In a comparatively short time, a bridge was available for testing, and designers decided to load the structure to failure to determine its actual capabilities. Some of the loading techniques were unusual to say the least. On one occasion, a World War I vintage tank was placed on the center of the span. A timber platform was built on top of the tank, and by means of a ramp, two more old tanks were "poised" on top of the first. The lower tank was then filled with pig iron, and several additional tons of material were placed on the span wherever there was room. The bridge held. Engineers ultimately loaded the bridge to failure, the top cord of the center panels finally buckling. These failure tests did produce

tables which units could use in deciding what form of Bailey they were to build for a given situation.

The sense of urgency which dominated the design team and the cooperation it received from the British manufacturing establishment resulted in one of the shortest design-to-production periods of the war. It generally took a full year during the war for material to get from the drawing board to troops; however, design and production of the bridge proceeded concurrently and a pilot model was ready for test in less than five months. Production was under way in approximately seven months, and troops began receiving the bridge three months later. Therefore, by December 1941, British combat engineers had solved their problems of bridging for the new armored vehicles. By the time American engineers began wrestling with new bridge requirements for their growing armored forces, British combat engineer units had confirmed the value of the Bailey in actual operations.

The American side of the Bailey bridge story began in May 1940 when the U.S. Army's Ordnance Department announced that the existing 15-ton medium tank was obsolete. Ordnance plans called for a newer medium tank of 25 tons and a heavy tank of 50 to 60 tons. Like the British, the American engineers' first response was to modify existing

Engineers lift the bascule span of a class 70 Bailey bridge.
(Engineer School Library)

equipment to the extent possible. Ponton boats could be enlarged; the H–10 and the H–20 fixed bridges could be strengthened by adding girders and shortening spans; but these solutions tended to add weight and material to the bridge train. In addition, it would take longer to build the heavy girder bridges such as the H–10 and the H–20. The advent of pneumatic floats solved some of the problem of weight and transportation. These floats were lighter and more easily moved than the ponton boats; however, there was no corresponding easy solution for fixed bridging.

In early 1941, the Chief of Engineers directed the Engineer Board, the Corps research and development organization, to investigate heavier bridging, both fixed and floating. One project involved the design of H–30 and H–50 bridging which would ultimately support 30- and 50-ton tank loads across a 150-foot span. In August 1941, the Chief of Engineers also directed the Engineer Board to investigate the "modification of the British Bailey Panel Bridge to fit standard U.S. sections."

Engineers working on the now formally designated Project SP 341, Portable Steel Bridges for Heavy Loads, considered five factors. Bridge types to be adopted would be held to a minimum, not more than two, preferably one. Weight was to be held to a practicable minimum. The design should involve maximum simplicity of construction and provide for a clear span of 150 feet. Finally, the bridge material should be transportable on standard military vehicles. Much like the British team which developed the Bailey, American engineers were concerned with simplicity, weight, and transportability. Several existing American bridges met one or two of these criteria, but none met all of the requirements.

Because the staff of the Engineer Board's Bridge Branch was already overtaxed, the board decided to assign the design requirement for "a bridge of the Bailey type" to the engineering firm of Sverdrup and Parcel of St. Louis, Missouri. The civilian engineers were to modify the Bailey design to compensate for the differences in British and American rolling mill techniques. Aware of the potential benefits of having a bridge whose components were totally interchangeable with the British bridge, the board was sensitive to any unnecessary design changes. When Sverdrup and Parcel submitted

designs which made minor alterations in the floor system, the board told them to rework the design to comply with the British bridge.

After receiving a modified set of plans, the Engineer Board requested and received permission to procure a sample bridge for test and evaluation. The Commercial Shearing and Stamping Company of Youngstown, Ohio, received the contract for the first Bailey. A short time later, the contract was revised to include parts needed to adapt the Bailey for float bridge operations. The Carnegie–Illinois Steel Company of Pittsburgh, Pennsylvania, rolled the plates and shapes for the bridge. These initial contractors faced the two-fold problem of securing sufficient high-tensile steel for the bridge and developing the welding techniques for fabricating the panel trusses themselves. There was a great amount of discussion between the American contractors and their British counterparts. This exchange of information helped eliminate or prevent problems in the American manufacturing process.

The British approached the manufacturing of the Bailey differently than the Americans. In the United Kingdom, more than 600 firms manufactured parts of the bridge. A central depot assembled the major end items of the bridge and its assorted pins, connectors, and tools and issued complete sets to the Army. In Great Britain, companies of all sizes and types, from large engineering firms to small bedstead makers, window-frame makers, paper makers, and confectioners made parts of the Bailey. A rigorous inspection system using both master and contractor gauges ensured uniformity and therefore interchangeability. In addition, vital panels had to pass proof tests in the early days of the war.

By contrast, the American Army contracted with companies for complete bridge sets. Ultimately joining the Youngstown company were the Ceco Steel Products Company of Chicago, the International Steel Company of Evansville, and the Virginia Bridge Company of Roanoke. A number of smaller companies produced stampings, castings, bolts, pins, and wrenches. Given the goal of complete interchangeability between British and American bridges, it was critical that specifications be adhered to stringently.

In late 1942, the sample bridge was ready for test. The Chief of Engineers directed the Engineer Board to evaluate

The recommendations passed to the Chief of Engineers from the Engineer Board did not, however, correspond with the suggestions of the Bridging Branch. There was sufficient support for the Bailey on the board to change one of the recommendations. The board recommended that the H–10 be retained, following the suggestions of the Bridging Branch. However, the board recommended that the panel bridge (Bailey type) be procured in place of the H–20 bridge. The flexibility of the Bailey and the possibility that it could serve both American and British engineers overcame the concerns about the close tolerances and exact measurements required during the manufacturing process.

It is possible that some American engineers were not overly concerned about the precision production challenges posed by the Bailey. The British had attained standardization for component parts in spite of the fact that hundreds of companies made parts of the bridge. The British ensured their interchangeability through the use of fabricator gauges and a single master gauge. The use of those instruments precluded acceptance of parts which did not meet specifications.

Early in the fabrication phase for the test bridge, American engineers borrowed a set of gauges from the Canadians. These gauges had been sent to Canada from England as part of an education program on manufacturing the bridge. However, the Engineer Board recognized that, in time, American manufacturers would have to have their own set of fabricator gauges. A master set would be used to ensure the accuracy of the fabricator gauges. After some hesitation, the Chief of Engineers approved the procurement of 25 sets of Bailey bridge gauges for the British army and six ponton-coupling gauges for use with the floating Bailey equipment. The Chief of Engineers approved the production of these gauges for the British in consideration of their cooperation in supplying the original master gauges via Canada. It was not until September 1942 that the engineers found two firms—the Industrial Tool and Die Works of Minneapolis and the R. Krasberg and Sons Company of Chicago—to produce the gauges. The contractors completed production of these instruments in January 1943.

As bridge sets became available, the Engineer Board intensified its testing. In an effort to develop procedures for

employing the bridge while also evaluating its capabilities, the board conducted troop tests with the 31st Engineer Combat Regiment at Fort Belvoir. The 31st erected a number of bridges, both fixed and floating, with the Bailey panels. These troop tests confirmed the structural soundness and flexibility of the bridge. Board members concluded that the British capacity ratings for various spans were conservative, but did not recommend new classifications in their report to the Chief of Engineers. The success of the Bailey as a float bridge was significant in light of problems with the steel treadway float bridge which occurred in the fall of 1942.

In four separate instances—two at the Desert Training Center, one at Fort Benning, and one at the Tennessee maneuvers— tanks crossing steel treadway float bridges had slid into the water. In each instance, excessive weight or off-centered loading caused the bridge to twist and floats to come out from under the treadway. Seven soldiers were killed in these incidents. Although the armored force insisted that the bridge was acceptable, engineers moved to improve the safety of the treadway and increase the size of the floats. These incidents also increased interest in the Bailey's capabilities as a float bridge.

Assembly of a floating Bailey bridge. *(Engineer School Library)*

Confirmation of the 31st Engineers' success with the Bailey as a float bridge came with the Tennessee maneuvers

of 1943. The 551st Engineer Heavy Ponton Battalion constructed a 590-foot floating Bailey at Rome Ferry, Tennessee, during the second phase of the maneuvers. A large part of an armored division crossed the bridge shortly after its completion. Engineers monitored the bridge, which was under constant use for approximately one week. Engineers found that the Bailey did not require significant additional transportation assets when used with the 25-ton ponton. After the maneuvers were concluded, the 551st considered the floating panel bridge (Bailey type) superior to any standard ponton bridge. The battalion's report stated that the bridge was more stable and would carry a heavier traffic volume in given time. Maintenance problems were fewer and, as in earlier tests, drivers were more confident crossing the through-type bridge.

Although tests to officially confirm the Bailey's capabilities as a float bridge were not concluded until the end of 1943, troop tests in the United States and combat use in Europe had already established the bridge's amazing potential. Ironically, these same tests identified a problem with the production of the Bailey. The problem went to the core of the concept of an interchangeable bridge for both the British and the Americans.

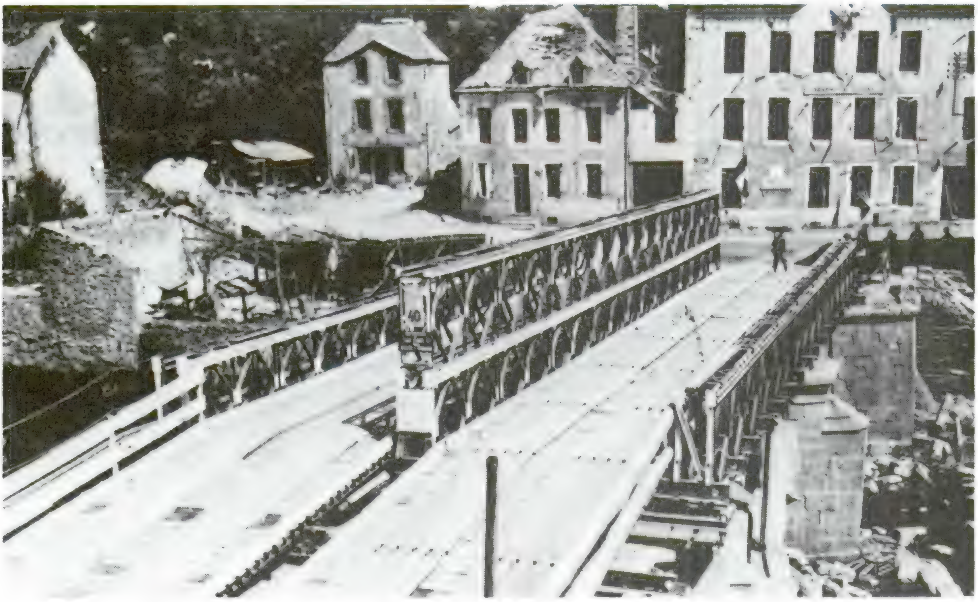
During the troop tests with the 31st Engineer Regiment, board members found that some of the panels were off-size. The cause was faulty fabrication. These components had to be altered by grinding or spreading to fit with the other parts of the set. In theory, the fabricator's gauges should have detected these panels before they were issued to troops. In October 1943, the board decided to recheck the gauges to ensure that they were still accurate. The engineers again borrowed the Canadian gauges to use as a master. The comparison revealed that many of the gauges had been damaged in use and others were not accurate due to poor quality workmanship. This necessitated a thorough reconditioning and repair of the American master gauge and the fabricator sets as well. The engineers then instituted a program whereby the gauges were periodically reconditioned through a schedule that would not interfere with the manufacturing of the bridge sets.

The damage to the concept of interchangeability had already been done. It was not until August 1944 that

engineers had gauges that corresponded in tolerances to those of the British. As a result, the 850 American-made Bailey bridges acquired in 1944 had to be segregated from the British bridges because the components were not interchangeable. Tests conducted by the Australians on American-built Baileys revealed that 75 percent of the panels were not interchangeable even with each other. After the war was over, the British returned the 25 gauge sets the Chief of Engineers sent them in 1942 because they were of such poor quality that they were practically worthless. The system of mass production and quality control applied to making the Bailey in the United States failed within the context of interchangeability.

The failure of precision production did not keep the Bailey from becoming the most versatile military bridge in history. Its greatest use was in Sicily and Italy where German demolitions created hundreds of river and dry land obstacles. In a 20-month period in Italy, the American Fifth and British Eighth Armies constructed more than 3,000 fixed Bailey bridges to cross different streams. The combined lengths of these bridges was 55 miles, with an average length of 100 feet. Engineers found that the panels could also be used to construct piers for bridges. The Eighth Army built one Bailey using panel crib piers of 70 feet. When Germans foolishly dropped bridge spans but spared the piers, Baileys were used to restore mobility quickly. For example the Germans dropped 19 spans of the Sangro River bridge, but left 14 piers standing. British engineers built a 1,126-foot Bailey on the standing piers. The Bailey was also adapted as a suspension bridge in Italy. One such structure over the Volturno River carried 240,000 vehicles in eight months.

In northwest Europe, the Bailey was used primarily as a fixed tactical or line of communications bridge. For the war of movement across northern France, most divisions relied on steel treadway floating bridges. These were much faster to use and easier to transport than the Bailey. The Third Army erected 53 treadway bridges with a total footage of 20,166 feet compared with 11 floating Baileys with 9,380 feet aggregate length. General George Patton's command built almost 27,000 feet of fixed Bailey bridging compared to approximately 9,800 feet of fixed treadway bridging. During the



Dual passageway class 40 Bailey bridge across the Varenne River, France. (Engineer School Library)

Rhine River crossings, American armies built nine floating Baileys, using the British Mark V pontons.

On the other side of the world, the Allies used Baileys primarily in the China–Burma–India (CBI) theater. There engineers constructed Baileys prior to building heavier, more permanent bridges. American engineers built the longest clear span of the war, 420-feet, over the Shweli River. This was a suspension Bailey with the two end towers built out of Bailey panels.

From a sketch on the back of an envelope from Donald Bailey's pocket, the Bailey bridge emerged as one of the most significant developments of the war. It, much like the Douglas DC-3, was a work horse in its own area. Virtually every Allied nation used the Bailey during the war, and many countries continued to use the Bailey, with various modifications, into the 1980s.

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Landing Mat Development at WES

by Michael C. Robinson

The U.S. Army Waterways Experiment Station (WES) at Vicksburg, Mississippi, made a host of contributions to American successes in World War II. The station, founded in 1929 as the Corps' hydraulics research facility, set aside most of its civil works program after Pearl Harbor and began focusing on military-related research and development. The loss of 631 employees who enlisted in various branches of the armed services aggravated this transition. With many men at war, WES hired and trained women to fill various technical and support roles. Captain Kenneth E. Fields, who became the station's director in September 1939, left to join the Manhattan Project in December 1941. Consequently, Gerard H. Matthes became the only civilian director of WES in the research facility's history.

In the midst of transition and restaffing, WES took on a broad agenda of research and support roles that included developing artificial harbors for the invasion of northern Europe, improving the trafficability of military vehicles in many types of terrain, and using its vast library resources to gather historic hydrologic data in support of Allied crossings of the Rhine River.

WES also made far-reaching contributions to the development of criteria for the design and construction of airfields including airfield drainage, soil stabilization, and flexible pavements. One phase of this work consisted of developing and testing "expedient surfacing" as the need arose for rapidly constructed airfields designed for short periods of intensive use.

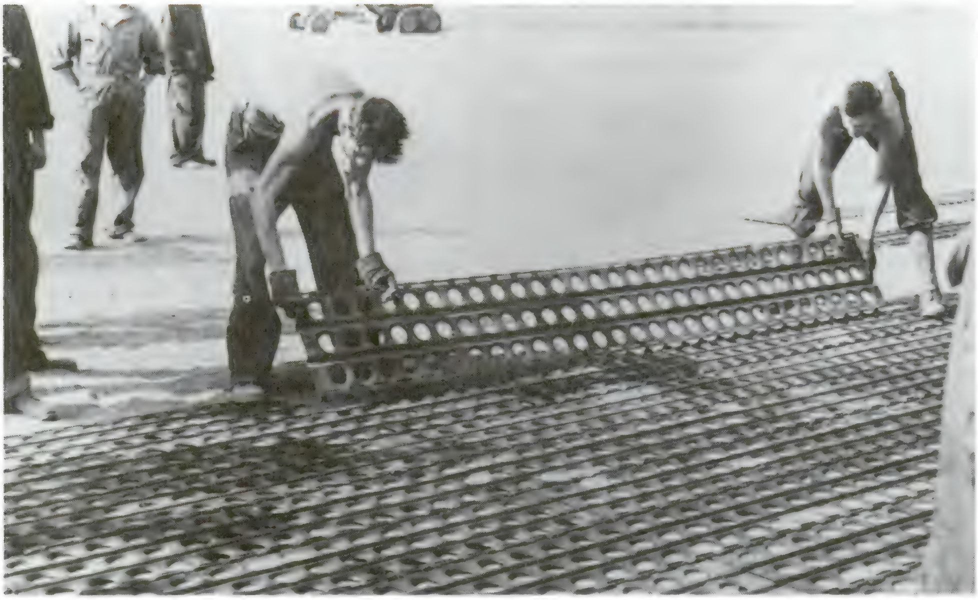
Landing mats tested and developed by WES made a significant contribution to Allied victories in Europe and the Pacific. Mats saved time and building materials by offering a reliable alternative to assembling the thousands of tons of base material, sand, and asphalt required in more permanent, conventional designs. The capability to rapidly deploy these temporary landing strips was of utmost importance in

maintaining air superiority. Raymond Tolbert of the Office of the Chief of Engineers described this innovation as "an engineering device of important military significance that was largely responsible for the growth and maintenance of Allied air power." WES continued to test and improve landing mats until 1975.

Work on expedient surfacing in Europe predated landing mat research and development in the United States. As air power became a central part of the military capability of the leading European powers, France and England experimented with various landing surfaces to accommodate large fleets of aircraft. Before the war began, France deployed on its airfields a "chevron grid" mat it had developed. France's agricultural practices dictated the mat's design. Since most of the country's airfields were sited on previously cultivated land, soil conditions required a rigid bar-and-grid type mat capable of withstanding heavy landing loads. The gridwork of the mat consisted of longitudinal T-sections interconnected with a zig-zag bar forming large panels that exhibited a herringbone pattern. Bolts and nuts locked the sections to one another.

Conversely, Britain developed a light, flexible-mesh mat that it deployed on its grass covered airfield sites. This design permitted the construction of airfields at locations previously considered unacceptable, and it could also be used to build temporary roads for military vehicles. Fabricated into large rolls, the mat could follow the contours of the ground. The openings in the mesh allowed vegetation to grow relatively unhampered, which provided a natural camouflage, giving the runway the appearance of a pasture from the air. Workers could lay down the mat sections at a rapid rate. On one occasion, the British constructed a landing strip measuring 150 by 3,000 feet in only 15 hours. Easy to disassemble, the mat required only the removal of connector clips for rerolling.

The U.S. Army Air Corps took a lively interest in the British and French landing mats. In December 1939, the Air Corps asked the Army Corps of Engineers to study these European mats and to select or modify one for use by American planes. The Air Corps provided $30,000 for testing. After examining the performance of the French and British mats, however, the engineers concluded that neither product



Expedient construction of a landing field using pierced plank mat.

by compensating for the strength lost by removing a portion of the metal. Each steel plank was 10 feet long, 15 inches wide, and 1/4-inch thick and weighed about 70 pounds. The panels joined together by a locking mechanism consisting of alternating rows of slots on one side and sliding, interlocking projections on the other. Spring clips kept the connectors in position. Although Greulich solved the problem of mat linkage, the Army continued to test other designs proposed by manufacturers throughout the war.

To test the mats, WES engineers and scientists put in place standard procedures for conducting mat research and comparing test results. Mats selected for appraisal underwent both engineering and service testing. The engineering tests usually indicated the inherent structural adequacy or design deficiency, while the service tests examined mat behavior under airplane traffic. The laboratory phase of the engineering evaluation consisted of bending tests, shear and tensile tests of the interlocking connectors, as well as a physical and chemical analysis of the metal. Researchers compared stress-strain data from bend tests with those for other mat types. Large vehicles loaded with thousands of pounds repeatedly traversed test mat sections to evaluate mat behavior under stress and determine the strength of connectors. Many

Waterways Experiment Station researchers test experimental mat.
(Waterways Experiment Station)

prototype mats failed the engineering tests and never went into production. During service testing, Corps engineers subjected mats to airplane traffic ranging in weight and size up to heavy bombers of 60,000 pounds or more. The research design included observations on:

- Structural adequacy under static and dynamic loads.
- Braking action.
- Skidding characteristics.
- Tire abrasions.
- Time checks on laying operations.
- Durability.

The most extensive tests conducted at WES occurred in 1943 and 1944. By this time, the government had accepted PSP and several other types, but questions remained regarding mat performance under contrasting soil conditions. Since the armed services were deploying mats throughout Southwest Asia and Europe, these critical performance data were badly needed. Accordingly, the Office of the Chief of Engineers, in cooperation with the Engineer Board, planned an extensive research program to correlate mat performance under different loads with various soil and base courses. The

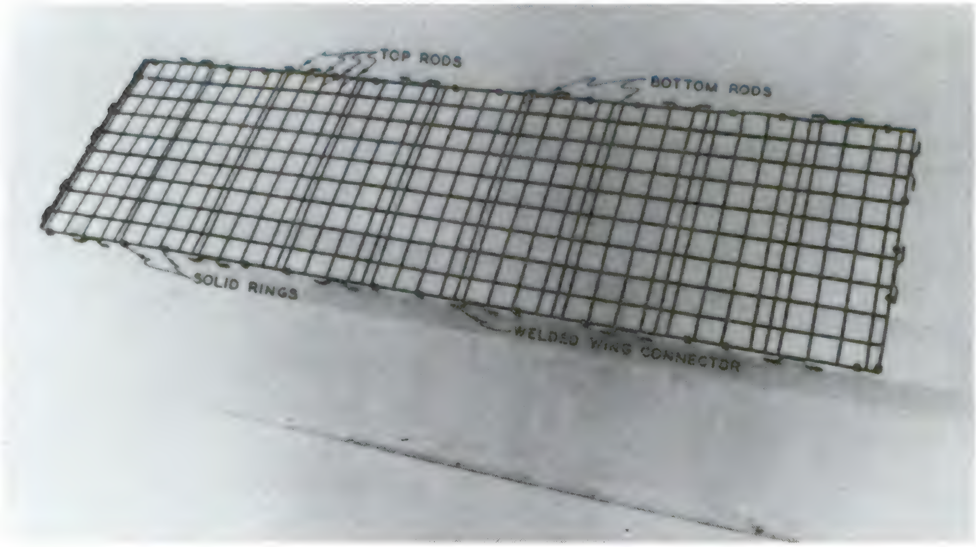
Operational testing of pierced steel plank mat. (Waterways Experiment Station)

tests included careful use of the recently developed California Bearing Ratio (CBR) to determine the penetration resistance of each soil type.

The WES Flexible Paving Laboratory received this important and complex assignment. The purposes of the investigation included determining the proper thicknesses of base courses, understanding the capabilities of landing mats placed on silt and clay, analyzing new techniques for joining sections together, and comparing the performance of various experimental mats with the standardized types already used in theaters of operations.

WES conducted most testing at two locations near Vicksburg. A site near Mounds, Louisiana, featured a fat clayey subgrade known locally as "buckshot." By contrast, the "Rifle Range" site south of Vicksburg offered a silt-loam soil. At these locations, WES conducted tests using a LeTourneau Tournapull earth-moving machine loaded progressively with 15,000, 37,000, and 60,000 pounds of weight. The research team ran tests on no less than 15 mat types, including standard steel mats, experimental steel mats, experimental aluminum alloy mats, and an array of experimental wooden mats developed by General Electric and other companies.

The tests generally vindicated deployment of PSP and a heavier bar-and-rod grid mat recently adopted. Both performed better than experimental types examined, and when



Experimental bar and rod mat. *(Waterways Experiment Station)*

laid on a thick base course of sand or gravel could support 60,000-pound wheel loads, the weight of the largest bombers. One type of laminated wood mat actually outperformed any of the steel mats tested. Its production involved building a lumber gridwork of two-by-fours and filling the interstices with subgrade material, but it was not practical for wartime conditions. The research program also determined the thickness required for aluminum mat to equal the trafficability of PSP.

The WES testing program, combined with favorable reports from airfields throughout operational theaters, reaffirmed the preeminence of PSP. The heavy bar-and-rod was relegated to a supplementary role and production of lighter types other than PSP ceased. Thereafter, research focused on refinements such as improving the durability of connectors.

Production ease and speed shaped decisions on which mat type to adopt. The plank type could be easily manufactured and steel companies readily modified their presses to quickly stamp out large quantities. However, this mat did not camouflage easily. Nevertheless, the Army decided in December 1941 to procure the PSP mat primarily because of its ease of production. It satisfied all criteria for a heavy-duty plank mat. Although the Corps of Engineers never obtained the light-duty mat sought by the Air Corps for pursuit and observation planes, field commanders were happy

with the all-purpose PSP. Several grid designs facilitated subgrade aeration and camouflage, but limited production facilities retarded their deployment. In October 1943, the Army approved two types of grid mat developed by the engineers, but their role would be supplemental. Alternate grids were used only when the supply of PSP failed to fulfill requirements. During World War II, the United States produced a staggering 800 million square feet of PSP. All other types totaled less than 50 million square feet.

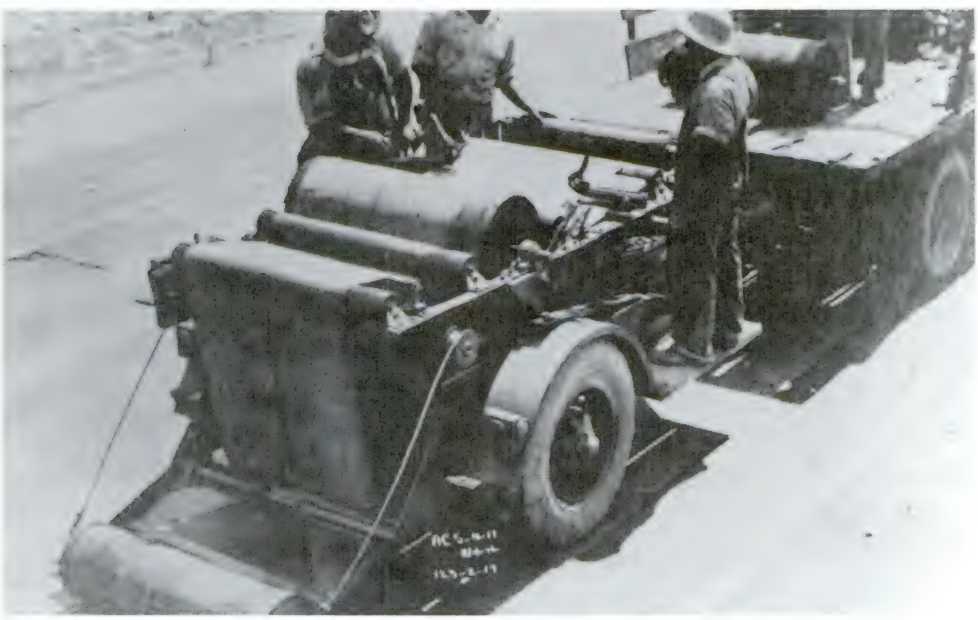
Even though PSP became the landing mat deployed nearly universally, the Air Corps seriously considered using aluminum. This material offered the opportunity of reducing the mat's weight so that smaller planes could carry it into areas inaccessible to heavier aircraft. The Corps subsequently asked the Aluminum Company of America to work with various contractors to develop the new mat. This effort resulted in the pierced aluminum plank (PAP) mat. The design of the lightweight aluminum-alloy planks mirrored the standard PSP. The PAP units measured 15 inches by 10 feet, but they weighed only 35 pounds, or about half of their steel counterparts. Although lighter, the PAP performed adequately. Designers obtained rigidity by increasing the aluminum sheet's thickness approximately 40 percent over that of steel. Since its service life was only half as long, the aluminum landing mat never replaced steel during World War II. It remained a useful supplement to PSP that facilitated airfield construction in remote areas and other locations requiring efficient use of air transportation.

WES also helped to develop prefabricated bituminous surfacing (PBS) which facilitated rapid temporary airfield construction. This technique was invented in Canada, developed by the English, and improved by the United States. Its objective was to place a waterproof fabric over graded and compacted natural soil. The fabric would provide a means of keeping the soil dry while offering a safe landing surface for aircraft traffic.

Intensive investigations at WES resulted in a membrane that could be produced in great quantities and give satisfactory results. Popularly known as "Hessian Mat," the 1/4-inch thick material went into production in early 1944. The Allies placed this relatively inexpensive mat on more than 100

Prefabricated bituminous surfacing.

landing strips in Europe between D-day and the crossing of the Rhine in March 1945. It provided good service under a steady stream of cargo and fighter planes as well as medium bombers. The PBS comprised nothing more than burlap that was impregnated and coated with asphalt, giving the appearance of roofing material. The relatively light PBS could be put down in strips at a rate of 2.5 to 4 miles per hour. Crews used a "stamplicker" machine that wet one side of the mat with a solvent which softened the asphalt and produced



The stamplicker, *a machine for laying prefabricated bituminous surfacing.*

a sticky surface. Then a second layer was applied so the bonded surface provided a thin, weatherproof, and dustproof landing strip. A fine layer of sand placed on the surface enhanced friction and reduced skidding. Alternately, the bituminous surfacing could be used in conjunction with steel landing mats when a dust palliative was required.

The prefabricated bituminous surfacing proved as easy to repair as it was to lay. Two laborers with a mop, bucket, and strip of PBS could simply repair small failures by swabbing the mat, laying it, and then just walking back and forth on it to pack it in place. Repairing larger problems caused by bombing and soft spots formed by trapped water involved peeling back the PBS, replacing the subgrade, and putting down a fresh strip. The nickname Hessian came from the fact that Hessian migrants to Dundee, Scotland, had woven Indian jute into mats more than a century before.

Once designed, tested, and ordered for procurement, the steel and aluminum landing mats had to be produced in great quantities. To meet the demands of the armed forces, steel companies retooled to accommodate landing mat production. Some 30 factories made pierced steel plank during World War II. Normally, processing facilities acquired the precut steel used for the planks. A conveyor belt carried the raw steel to a machine that impressed the metal with two ribs running the entire length of the plank. A second press pierced and flanged the metal, while a third formed the slots and bayonet locks. After the steel was cut into 10-foot sections, a fourth press bent the locks so they would fit securely into the slots. Once formed, the mat went through a finishing process. This consisted of dipping the mat into a degreasing solution that removed residues before paint was applied. The mat received an Army-green camouflage coat and was then baked, cooled, and packed for shipping.

The armed services developed field techniques to rapidly remove and reassemble PSP and PAP. As the enemy fell back, what had once been advanced airfields became rear bases, and many of the strips fell into disuse, requiring the moving of the portable mats to more forward areas. Removing the planks without damaging them for use elsewhere was of great concern. Innovation and adaptation solved the problem.

Simple railroad picks removed the locking clips and helped separate the mats.

Aircraft takeoffs and landings, as well as bombing attacks, subjected landing fields to constant stress. The need for on-the-spot repairs led to the development of portable reconditioning plants. The portable units, which weighed 60 tons each, could be carried in a cargo plane. Soldiers could recondition an entire airstrip 300 feet wide and 1/2 mile long in less than a week. The plants consisted of two main machines, a roller-leveler to straighten the mats and a brush-cleaning machine to remove soil and debris. They made a significant contribution to the war effort by making rapid repairs and reducing steel consumption through reuse.

The need for a portable landing mat arose time and again throughout the war in both Europe and the Southwest Pacific. During the New Guinea campaign, for example, enemy forces began advancing across the Owen Stanley Mountains. In response, Army engineer units constructed a PCP emergency airfield well behind enemy lines at a place called Dobodura. Cargo planes flew in the landing mats as well as all construction equipment, troops, and supplies. The fighter planes operating from this emergency runway contributed to the early Allied victories in New Guinea.

During World War II, the United States manufactured a quantity of landing mats capable of building a steel roadway around the world's equator. Some 2 million tons of mat costing in excess of $200 million accounted for enough steel to build 650 10,000-ton cargo ships. WES and other Corps elements conducted the testing that enabled the nation to develop and rapidly manufacture this essential strategic item. These pioneering efforts later redounded to the nation's benefit as heavier jet aircraft with high tire pressures evolved. Research on landing mats continued at WES for more than three decades, and especially intensified during the wars in Korea and Vietnam. The station published more than 90 technical reports on this subject, acquiring a broad institutional expertise.

WES research and development work on landing mats clearly enhanced the Allied ability to rapidly deploy and advance its air power during World War II.

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Airfields for Heavy Bombers

by Anthony F. Turhollow

The Corps of Engineers inherited a major technical challenge when the War Department in late 1940 assigned it the responsibility for constructing the air bases required by the nation's land forces. The problem confronting the Corps was to build airfields capable of serving the very heavy bombers then under development, flying machines that would assume a central role in the United States' war fighting strategy.

The engineers learned the magnitude of the challenge they faced in May 1941 when the first experimental long-range bomber, an XB-19 built by the Douglas Aircraft Company at Santa Monica, California, taxied out of the company's

The 42-ton Douglas XB-19 poised for takeoff in January 1942.

hangar at nearby Clover Field. Designed to weigh 80 tons when fully loaded, the empty test plane broke through the apron to a depth of about 1 foot. Only seven weeks later, after a new concrete runway had been completed, could the aircraft make its maiden flight. Observing the plane's landing at March Field, California, engineers from the Corps' Los Angeles District reported that a depression and cracks appeared in the concrete runway where the plane had decelerated. Pointing out that weather and groundwater conditions were ideal during this test, the district engineer, Lieutenant Colonel Edwin Kelton, observed that after heavy

rains, landings by fully loaded B-19s might inflict "extreme damage" on available runways. The engineers received a respite when the XB-19's engines proved unequal to its great weight, but the B-29, a Boeing bomber of nearly equal weight, remained under development.

The XB-19 test clearly demonstrated that super bombers would require super airports for which there were few engineering guidelines. The high landing speeds, pounding vibrations, and violent propeller blasts of the new, heavy bombers would evidently require revolutionary methods of runway construction. At a minimum, the airfields designed to serve these planes would need stronger pavements, gentler grades, improved subsurface compaction, more extensive drainage structures, and better dust control. To accomplish these improvements, the engineers would have to devote, in a limited time, a considerable effort to research and experimentation.

The Air Corps had set forth rigorous requirements for air strips to accommodate around-the-clock, all-weather operations by B-19s. Runways for these bombers were to possess the following characteristics:

- Inherent strength to carry wheel loads up to 100,000 pounds.
- A stress load value of 500 pounds per square inch under impact.
- Safeguards against any weakness caused by infiltration of water into the subgrade.
- High skid resistance in wet weather.
- High visibility at night.
- A low crown, to reduce the hazard of ground looping.
- Low rolling friction.
- Freedom from loose particles.
- Durability, so that they would require no maintenance except repairs of bomb damage.

The Corps of Engineers quickly marshaled its resources and those of the nation's engineering profession to meet the requirements of the Air Corps. William McAlpine, the senior engineer who in 1941 headed the Engineering Section of the Corps' Civil Works Division, arranged for the Ohio River

Division to test the applicability to airfield construction of current concrete design principles. The Cincinnati-based division's Concrete and Soil Mechanics Laboratories, which had been organized in 1934 for the Muskingum River project, provided distinguished research talent for this inquiry.

The division conducted a series of experiments on the 7-inch reinforced concrete apron at Wright Field, Ohio, and on the 6-inch concrete surface at Langley Field, Virginia, the first built over a clay subgrade and the second over a sandy silt. Using a hydraulic jack and a bearing plate, the engineers carefully observed as they placed 60 one-ton concrete blocks, one after another, on the centers, edges, and corners of concrete slabs. At the same time, experiments in which planes landed on lime-coated runways provided better information about tire imprints. The experiments demonstrated that the classic analysis of stresses in concrete pavements developed by Harald Westergaard, dean of Harvard's Graduate School of Engineering, provided the engineers a "very, very wonderful handle," as Soils Mechanics Laboratory head Robert Philippe reported. At division headquarters, Evan Bone meanwhile developed a family of curves which would enable any engineer, once he had determined the rigidity of the subgrade, to quickly calculate the thickness of concrete required for any wheel load up to 30 tons.

While these experiments largely resolved the theoretical questions involved in the use of concrete pavement, they did not address the specifications of the asphalt runways which the Corps of Engineers hoped to build for the new, heavy bombers in distant theaters of operation from which the Americans could carry the war to the enemy homelands. Colonel James Stratton, who had supervised two large New Deal dam and reservoir projects before succeeding McAlpine as chief of the Engineering Division at Corps headquarters in December 1941, organized a series of tests to determine the subsurface compaction and pavement thickness and deflection demanded by the heavy bombers.

Fortunately, highway engineering practices provided a starting point. The advent of the automobile and truck in the first years of the 20th century had led to a demand for better roads, both asphalt and concrete. To meet this demand, state highway departments had cooperated in studies of

pavement design. The federal government also promoted investigative programs, as did the Portland Cement Association and the Asphalt Institute. Because a single-engine trainer had about the same wheel load as a heavy commercial truck, early airport designers used the same criteria as highway engineers. But for very heavy bombers, these criteria were insufficient and a new methodology had to be devised.

Stratton and his staff found that the California Bearing Ratio, a series of curves relating the thickness of asphalt paving required to support various loads to the nature of the soil which underlay the pavement, provided the most promising tool for analyzing the surfaces that would be required for the new bombers. The ratio had been developed by O. James Porter, a California state highway engineer, and had up to that time been applied only to loads which might be borne by asphalt roads. But after the highly respected Harvard soils engineer Arthur Casagrande affirmed the formula's potential value for determining the appropriate thickness of runways to support heavy bomber landings on different subsurfaces, Stratton embarked on a series of experiments designed to expand and test the design curves derived from Porter's ratio.

Prominent engineers in the Corps' airfield development program observed pavement experiments at the Stockton Test Track near Sacramento, California (Front row: Colonel Henry C. Wolfe, Harald M. Westergaard, Philip C. Rutledge. Standing on the tire: Arthur Casagrande, Thomas A. Middlebrooks, James L. Land, and O. James Porter).

Assisted by the staffs of five of the Corps' divisions, Stratton tested runway pavements built at Army airfields across the nation. The engineers towed equipment with wheel loads of 5,000 to 50,000 pounds over runways whose subsurface composition and compaction they had previously determined to calculate the limit of weight each could support. The results verified the potential of Porter's design curves to be extended to the weights and pavement thicknesses involved in surfaces that could support the new bombers. Actively participating in the studies, Porter concluded that pavements would fail if deflected more than 1/20 of an inch. However, leaders of the Air Corps' Building and Grounds Division and the Navy's Bureau of Yards and Docks remained skeptical at best, concerned that theoretical explanations had lagged behind experimental data.

In the spring of 1942, Stratton reorganized his unit, added new strength to his staff, and obtained the assistance of specialized consultants with outstanding reputations in their disciplines. With this "bunch of damn good engineers," the colonel brought his initial experiments to a productive conclusion. The concrete tests led to revisions in the curves for concrete thickness that the engineers employed in the design of rigid pavements and restricted the use of thickened edges in concrete sections. Refined concepts of flexible pavement design resulted from the tests evaluating critical deflection and the effects of repetitive loads. The studies also contributed to better understanding of material strengths, compaction methods, and curing techniques. New ideas on classifying soils, pointers on establishing and maintaining turfs, and improved methods of airfield drainage also emerged.

Corps teams digested this mass of information into three new chapters for the *Engineering Manual* and a comprehensive handbook for aviation engineer battalions issued in 1942 and 1943. A commentator in a leading engineer journal hailed the chapter on airfield drainage in the *Engineering Manual* as "a major contribution from the science of hydrology to the advancement of both civil and military aviation." Drawing upon extensive technical literature and applying the Corps' experience with flood control and river basin planning as well as the recent experiments, the chapter instructed budding airfield engineers on isohyetal maps,

rainfall intensity duration curves, design storm criteria, overland flow formulas, and infiltration theories.

Despite the intensive experimentation upon which it was based, the new chapter on airfield pavements proved less authoritative. Seeking to disseminate information quickly to emerging theaters of operations, the engineers wrote before all the experimental data were available and passed hastily over some problem areas. The authors dealt with frost action on a single page, provided a somewhat rudimentary discussion of paving materials, and left unresolved some important questions relating to the design of rigid pavements. The chapter even labeled as tentative the promising design curves for base and pavement thicknesses that had emerged from the experiments. Consultants like Porter were obliged to travel continuously to address these difficult issues.

More elaborately prepared experiments conducted in 1943 at Langley Field, Virginia; Eglin Field, Florida; and Barksdale Field, Louisiana, largely confirmed the design curves that the *Engineering Manual* had labeled as tentative.

A 120-ton pneumatic roller producing firmly compacted soil.

The tests did indicate, however, that somewhat thicker bases than anticipated were required on sandy silt and black clay and that somewhat thinner ones would suffice on clean, well-drained sand. The new chief of Stratton's Airports Division, Gayle McFadden, who had directed the construction of

New York's LaGuardia Field and Washington's National Airport, kept the manual updated with the latest findings.

In August 1943, Corps districts around the United States began a series of tests of the load-bearing capacities of the runways in their regions, relying on the California Bearing Ratio curves and the plate-bearing test results for ready analysis. In the fall of 1943, as American airmen trained on the B-29s that were beginning to emerge from production lines, the engineers "beefed up" runways with asphalt overlays or additional slabs of concrete where the tests showed these were warranted.

President Roosevelt decided to deploy the B-29s initially to India and China, believing that the planes could make their most strategically significant contribution against the relatively unscathed Japanese homeland. Shortages of modern construction equipment and materials in the receiving Asian countries and a resulting reliance on large groups of laborers and more traditional materials led the engineers to conduct new tests of runways made with these supplies and methods. The Corps' Waterways Experiment Station, which had just completed a new flexible pavement laboratory, took the lead on these alternative materials tests. After overseeing a series of experiments at Marietta, Georgia, not far from the B-29 assembly plant that the Corps had built there, test director John Griffith undertook the daunting assignment of providing blueprints for the overseas very heavy bomber fields.

The Army meanwhile gave some civilian Corps soil experts direct commissions as senior officers and sent them to China and the Pacific to help build airfields prepared to handle the new B-29s. It was from the former fields that the Air Corps' Superfortresses, boasting a range of 3,250 miles, began in June 1944 the bombing raids against Japan that ended the immunity from attack previously enjoyed by the Japanese home islands. In 1945, Army engineers built B-29 fields on Saipan and Guam in the Mariana Islands from which the American bombers attacked Japan from still closer range. The Asian and Pacific fields successfully bore the demands of the new aircraft, each of which when fully loaded weighed 70 tons, more than the heaviest tank employed

by the U.S. Army in the war and double the weight of the Sherman tank, the armored forces' workhorse.

Under the stress of war, the engineers attained for the United States effective world leadership in airfield design. The Corps' research effort yielded advances in engineering knowledge that won broad professional acclaim when published in the *Proceedings of the American Society of Civil Engineers.* The *National Aeronautics* journal commended the findings to "civilians planning the large commercial airports of the future." Militarily, the wartime airfield research program left the United States prepared to meet the needs of its most advanced aircraft wherever around the world the demands of the final years of World War II and the ensuing strategic competition with the Soviet Union required their deployment.

Sources for Further Reading

The chapter on "Airfields for Very Heavy Bombers" in a book by Lenore Fine and Jesse Remington, *The Corps of Engineers: Construction in the United States* (Washington, 1972), provides a well-written and detailed study of the Corps' wartime airfield research and development effort.

Other related readings include an article by Major General Henry H. Arnold, "The Air Forces and Military Engineers," in *Military Engineer,* 33 (1941): 545–548; two chapters on aviation engineers in Volume 7, *Services Around the World* (Chicago, 1958), of W. F. Craven and J. L. Cate, *The Army Air Forces in World War II*; and "Military Airfields, A Symposium," *Proceedings of the American Society of Civil Engineers,* 70 (1944): 27–89.

SECTION IV
Civil Works

The Corps of Engineers has been permanently involved in civil works construction and operations since 1824. With nationwide flood control and navigation responsibilities, its dams dot America's landscape, controlling floods, providing hydropower, supplying water, and offering recreational opportunities. Corps locks help move barges along the nation's rivers, while the Corps also ensures that American harbors are kept open for ocean and coastwise vessels. Indeed, until the Corps received the military construction mission at the beginning of World War II, the principal focus of the Corps was on civil works, although it also constructed coastal fortifications and made major contributions to enhance combat effectiveness during war.

The role of the Corps in civil works measurably increased during the New Deal of the 1930s, partly the result of the need to employ millions of people left destitute by the Great Depression and partly in response to a series of floods that wracked the Northeast and the Ohio Valley in 1936 and 1937. The Flood Control Act of 1936 declared flood control a legitimate federal responsibility and made the Corps of Engineers the nation's premier flood control agency. This one act alone authorized hundreds of levee and reservoir projects and forced the Corps to reorganize, develop new approaches, and, in general, greatly increase its construction capability. However, just as many new flood control projects were commencing, the specter of war forced the nation to switch its priorities.

As the United States became more involved in supporting the Allied war effort in 1940–41, the legislative and executive branches faced the delicate and controversial task of offsetting the cost of increased military activity by trimming domestic expenditures. Public works projects were an obvious target. They cost billions of dollars and some were marginally

justifiable. Certainly, most politicians agreed, some projects could—and must—be temporarily shelved until the return of peace. Yet, the construction of bridges, dams, airports, and highways provided employment and stimulated the economy. Any decision to halt construction of a project was bound to have political ramifications. To reduce the politics and lessen the disputes over which projects to halve or delay, the executive branch established new bureaucracies and procedures to determine domestic construction priorities. However, individual congressmen challenged the bureaucrats whenever arguable decisions adversely affected their constituents.

Although under restricted conditions, the Corps continued its civil works mission. Army engineers continued and even accelerated civil works projects vital to national defense. These included the maintenance of harbors and navigable rivers and the construction of flood control dams to protect vital industrial centers. At the direction of President Franklin D. Roosevelt, the Corps began planning postwar civil works projects over a year before World War II ended. One result was the Flood Control Act of 1944, which not only authorized a substantial number of projects, but established policies and programs that have influenced civil works activities to the present. In retrospect, then, what is surprising is not the decrease in the Corps' civil works activities during the war, but that many water projects were continued and that Congress, the Corps, and other federal agencies established an effective postwar civil works agenda.

The essays in this section describe some of the civil works activities during World War II.

The first essay gives a broad overview of the civil works program from 1939 to 1945, describing the difficulties of funding civil works projects during a period of changing priorities and increasing military expenditures.

The second essay analyzes the development of the Pick–Sloan Plan. Drafted during the war and authorized by the Flood Control Act of 1944, this plan provided the basis for the postwar development of the Missouri River basin's water resources.

Civil works projects in the St. Paul District and on the Mississippi River are described in the next two essays.

Another essay discusses the development of the Mississippi Basin Model using German prisoners of war labor. The model, designed and built by the Corps of Engineers' Waterways Experiment Station, reflected the importance of small-scale hydraulics research within civil works.

The final essay discusses the role of Portland District's Bonneville Dam in World War II. Constructed on the Columbia River, beginning in 1933 and dedicated in 1938, Bonneville provided electric power to public and private customers. During the war, it supplied power to shipyards, airplane factories, and aluminum plants scattered throughout the Northwest.

Together the essays reveal the continued large scope of civil works activities and the importance of the Corps' water resources mission to the war effort.

Civil Works Developments

by Martin Reuss

The war which broke out in Europe in September 1939 generated heated discussion over the appropriate level of United States' involvement. Some people argued that the country must support the Western democracies against the invading German army. Others thought the United States should stay out of Europe's problems. However, there was one point upon which all could agree. The United States would have to focus more attention on national defense and mobilization requirements.

Faced with shifting priorities and increasing military expenditures, people questioned whether public works projects, including the massive program of the U.S. Army Corps of Engineers, should continue. It was a contentious issue debated at all levels of government, but nowhere more than on Capitol Hill.

The fact was that, except for relatively brief periods of military conflict or when Congress had tightened the public works purse strings, civil works had been the principal activity of the Corps of Engineers since passage of the General Survey Act in 1824. Between 1919 and 1939, the Army engineers had spent nearly $2.5 billion on rivers and harbors, flood control, and fortifications projects. The work included the construction of Bonneville, Fort Peck, and Wilson dams and major flood control work on the Lower Mississippi River. To carry out this work, the Corps had an Engineer Department, a field organization consisting of 11 divisions and 46 districts. In 1939, the department employed 225 officers and 49,000 civilians.

During World War II, civil works activities declined, but not as drastically as is commonly thought. In 1936 and 1937, the Corps spent about $250 million annually on civil works. From 1938 through 1943, although funds and authorizations for new projects declined, the expenditures hovered between $200 million and $220 million. In 1944, the amount dropped to under $170 million and in 1945, to under $140 million.

Barges on the inland waterways system, which was vital for transportation of grain and fuel during World War II.

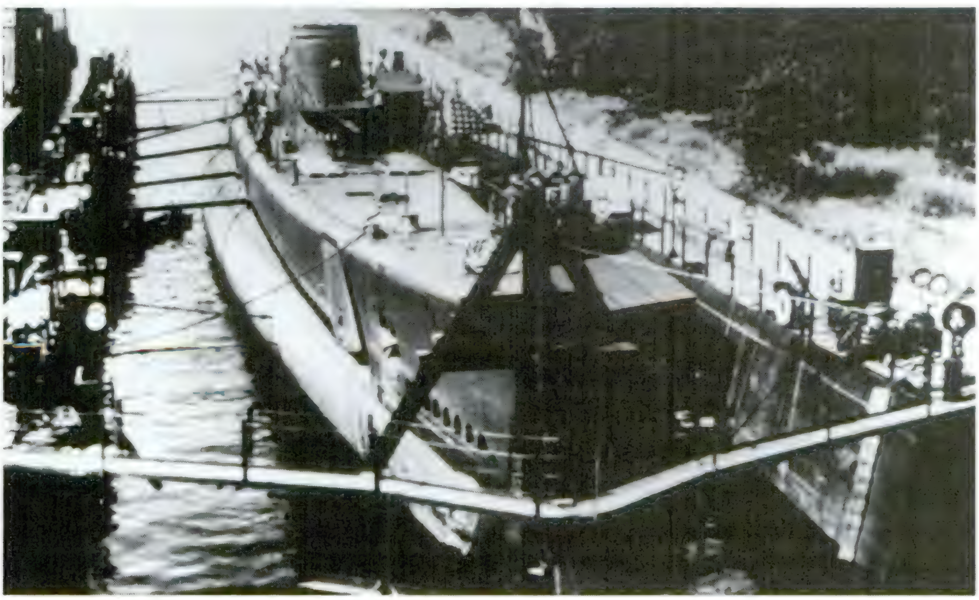
Much of this money was used for operation and maintenance requirements. Still, Corps leaders worried that the substantial decrease in new project authorizations and appropriations, which threatened major personnel reductions, would reduce the Corps' ability to discharge both its military and civil works functions.

Although the Corps focused on military needs, its civil works policies fundamentally changed during the war. This mainly resulted from the ongoing conflict between President Franklin D. Roosevelt and Congress over the appropriate way to develop the nation's natural resources. Ever since Roosevelt had entered the White House in 1933, he had been an ardent advocate of coordinated, multipurpose development of natural resources, including water projects. To that end, he established a National Resources Board, but the board never obtained sufficient authority from Congress to be an effective coordinating body. Already existing federal agencies with natural resources responsibilities, such as the Corps of Engineers, considered the board unnecessary, and Congress thought it a threat to legislative prerogatives. Roosevelt fought for his idea with the powerful rivers and harbors bloc within Congress, but was able only to chip away at the powerful coalition.

The coalition flexed its muscle once more in the spring of 1940. In May, Congress passed a "national defense" rivers

and harbors bill that authorized 23 new projects, a very modest amount compared to earlier rivers and harbors acts. Nevertheless, Roosevelt favored only 15, opposed 8, and decided to veto the bill. In his veto message, he wrote, "Regardless of every other consideration, it seems to me that the non-military activities of the War Department should give way at this time to the need for military preparedness." Several months later, he amplified his point in a news conference: "Now, I am trying to lay down a very strict rule that national defense means actually national defense, primarily munitions, and not things like highways."

The Senate Commerce Committee was not impressed and doubted Roosevelt's competence to determine which projects were defense related. The committee solicited advice from various agencies. The Chief of Engineers responded with a memorandum that incorporated submissions from the Navy Department, the Coast Guard, and the National Power Policy Committee. The Corps and the three other agencies continued to support six of the projects the President opposed. In the end, the Commerce Committee dropped only one project—navigation work on the Thames River in Connecticut—which



Submarine, headed downstream on a floating dry dock, was built at an inland port. The inland waterways system was used to send newly constructed warships to sea.

the Navy had initiated on its own. The total estimated cost for the 22 projects was $24.7 million.

Before the House Rivers and Harbors Committee, Brigadier General Thomas Robins, Assistant Chief of Engineers, testified that the Corps was complying "literally" with Roosevelt's desire to pursue only projects related to the war effort—"iron-bound national defense projects," in Robins' words. In the middle of October 1940, Congress once more passed the rivers and harbors bill, and this time the President approved it. The bill authorized 22 projects and modified 2 others. Of the total 24 projects, 14 were for the Navy, 7 for the War Department, 2 for the Coast Guard, and 1 for the National Power Policy Committee.

October 1940 was a good month for the Corps. A few days before the rivers and harbors bill passed, Congress approved two other bills that improved the Corps' situation. A supplemental defense appropriation gave the Corps $6.7 million for the construction of seacoast fortifications, and a Civil Functions Appropriation Act included some $13 million for navigation and flood control projects. The same act appropriated $40 million for airport construction under the Civil Aeronautics Authority (CAA). It was to be the beginning of a large effort that would eventually cost half a billion dollars and include 3,100 airfields. The CAA asked the Corps to perform extensive survey and construction work in the program.

The Roosevelt administration remained skeptical of congressional willingness to stay on a low public works diet. The Water Resources Committee (WRC) of the National Resources Planning Board—the bureaucratic descendant of the National Resources Committee—had organized a subcommittee in 1939 to draft a national water policy. Presumably, the policy would insure that water projects were carefully planned and coordinated. This, at least, would prevent Congress from authorizing projects which were contrary to sound, basinwide water management practice. In late 1940, the WRC had submitted a preliminary draft to the appropriate federal agencies for review and comment. On behalf of the Corps, General Robins dissented and suggested that, although the report contained some recommendations of merit, other suggestions seemed "unnecessarily complicated, time-consuming and not in the interests of efficiency and economy."

Major General Julian Schley, the Chief of Engineers, agreed to study the report and see if he could sign it, but the differences were too deep. One of the committee's recommendations had been to establish a permanent coordinating committee for water resources. Schley favored coordination, but he saw no need for a coordinating agency whose duties, in his opinion, would be "unnecessarily extensive and, in fact, duplicating in nature. Excellent cooperation is now experienced among the Federal agencies engaged in the planning for a [*sic*] development of water resources. Also, the duties of the proposed agency go far beyond coordination." Since he disagreed with a major and substantive part of the report, Schley regretted that he could not sign it.

Without the Chief of Engineers' approval, the report was printed, circulated, and then condemned to bureaucratic oblivion. In June 1943, the board (and the WRC) was eliminated when Congress refused to appropriate funds for it and specifically directed that its functions *not* be transferred to any other agency. In fact, the WRC's demise confirmed the obvious. Opposed by the rivers and harbors bloc as an unnecessary bureaucratic layer and ignored by almost everyone in Congress, the committee's death was merciful.

While the board withered, Roosevelt sought other ways to control public works spending. Again, this was not so much a response to military crisis as a continuation of New Deal attempts to coordinate and control planning. Indeed, such efforts preceded Roosevelt's presidency. The Employment Stabilization Act of 1931, passed during Herbert Hoover's administration, directed federal construction agencies to prepare six-year programs. The same day that Roosevelt signed the 1936 Flood Control Act, he directed executive agencies to send to the National Resources Committee a list of public works that might advantageously be undertaken during each year of a six-year period beginning in 1938. Roosevelt subsequently accepted the suggestion of the committee's chairman (and his uncle), Frederic A. Delano, that this effort be continued under the administration of the Bureau of the Budget.

Increasingly, the President turned to the Bureau of the Budget to coordinate and centralize planning. The bureau had been transferred from the Treasury Department to the

newly-created Executive Office of the White House in 1939. On 26 June 1940, the President signed Executive Order 8455, which directed all federal construction agencies, including the Corps of Engineers, to prepare annually six-year advance plans and to submit those plans, with yearly budget estimates and construction priorities, to both the Bureau of the Budget and the National Resources Planning Board. Furthermore, the agencies were to submit to the board and to the Bureau of the Budget any completed examinations, surveys, or investigations. The Bureau of the Budget would then advise the agency what relationship the proposed project had to the program of the President. That statement was to be included with the document when the agency submitted it to Congress for action. Additionally, the executive order empowered the board to request reports of various sorts from the construction agencies.

On 4 October 1943, a few months after the National Resources Planning Board was eliminated, Roosevelt signed Executive Order 9384, which modified but did not substantially change the coordinating intent of the earlier order. Powers formerly given to the board were transferred to the Bureau of the Budget, and the advance planning was reduced from six to three years. At first, Congress refused to appropriate sufficient funds for the bureau to carry out its review of public works. The situation did not significantly improve until after the war. Nevertheless, together the two executive orders initiated growing influence of the White House Executive Office over water resources programs, a process that continued spasmodically, but in the end successfully, for 40 more years.

One development that Congress used to justify its refusal to appropriate more funds for the Bureau of the Budget was the establishment by the Corps of Engineers, in December 1943, of a quadripartite agreement with the Department of Agriculture, the Bureau of Reclamation, and the Federal Power Commission. Essentially, this agreement replaced a 1939 tripartite agreement by which the Corps, Bureau of Reclamation, and Bureau of Agricultural Economics (Department of Agriculture) had agreed to exchange information and consult with one another in the preparation of reports. That agreement had led to increased cooperation, but had not

eliminated basic differences among the agencies. The new agreement was much the same as the earlier one, but Congress thought it undermined the argument for Bureau of the Budget coordination.

Whether sufficient executive branch coordination existed to insure efficient and effective water resources development was a question which stimulated animated disagreement. But whatever the extent of executive branch coordination, it was more than Congress could do. While concern for national defense might have been expected to reduce some of the normal, peacetime squabbling over the allocation of funds for public works projects, in fact the opposite was true. National defense became simply one more justification for project development. Few senators and representatives thought their favorite projects were unconnected with the country's defenses.

An example that epitomizes this congressional attitude was the debate on the Tennessee–Tombigbee Waterway, a project that would connect the Tennessee River to the Gulf of Mexico via the Tombigbee and Mobile rivers. While the project was too massive to be completed in time to alleviate the national emergency of the early 1940s, its supporters argued that precautions must be taken to better prepare the country for future crises. The waterway was particularly important for better access to the Tennessee Valley because of the growth of the defense industry in that area. Moreover, should the war end suddenly, supporters argued, it was important to have plans ready so that people employed in war-related activities could still find work. A basic issue, then, was whether Congress should limit itself only to short-term "national defense" projects or consider long-range needs.

The case of the Tennessee–Tombigbee was especially interesting because the benefit/cost ratio was only 1.16 to 1, among the lowest ever submitted, and because the Chief of Engineers had passed the survey report to Congress in 1939 without either approving or disapproving it. General Schley doubted that the intangible values assigned to the project—including $600,000 for national defense—could be easily substantiated, and he decided to let Congress make the determination. His decision was, to say the least, highly unusual. Congress voted against the project in 1939, but that did not

keep proponents from returning to the proposal during the next five years.

In 1939, the estimated cost of the Tennessee–Tombigbee Waterway was about $76 million. By way of comparison, the Army Air Corps paid less than $13 million for 524 Curtiss P-36 fighters in April 1939. B-17 bombers at that time cost about $200,000 each. The fact that waterway proponents continued to ask Congress during the war to authorize the project reflects the way in which national defense was exploited to help justify projects. The Tennessee–Tombigbee issue was unusual because its supporters, especially Representative John Rankin of Mississippi, were so vocal and because the project, even in peacetime, was being questioned. Yet, legislators brought many other projects before Congress, using the national defense shield to ward off both legitimate and illegitimate attacks. It is true that project authorization did not guarantee appropriations and that Roosevelt's intentionally narrow definition of "national defense" eliminated many projects from this category. Still, proponents hoped that some funding might be forthcoming, if not during the war, then soon after, once their project was authorized. Congress finally did authorize the Tennessee–Tombigbee project in 1946. Construction began in the early 1970s, and the waterway was completed in 1985.

As the war progressed, greater restrictions were placed on nonmilitary-related activities. On 20 October 1942, Donald E. Nelson, chairman of the War Production Board, issued a stop order for all nonessential civil construction projects. In response, the acting Secretary of War directed the Chief of Engineers to scrutinize the Corps' civil works program. Eventually, the Corps submitted two lists to the Facilities Review Committee of the War Production Board. One identified projects still under construction. The other listed suspended projects. The Chief of Engineers and the board then reviewed the projects under construction to determine if any more could be discontinued. The Corps consulted with other federal agencies before making recommendations.

In general, the stop order did not apply to the operation and maintenance of civil works projects since the continued operation of most projects was considered essential to the war effort.

Major General Eugene Reybold, the Chief of Engineers from 1941 to 1945, told a House Appropriations subcommittee in early 1942 that, "it would be hard to imagine a navigation or flood control project which does not contribute directly or indirectly to the war effort" and he suggested that even the smaller projects "are in general of more value to the nation at present than in ordinary times." About 250–400 rivers and harbors projects were maintained annually. New work was confined to projects of obvious military value, such as dredging New York Harbor, stabilizing the bank of the Chesapeake and Delaware Canal, widening the Sabine–Neches Waterway, constructing a new lock at Sault Ste. Marie, Michigan, and developing hydroelectric power capacity at Fort Peck and Bonneville dams.

However, flood control projects were far more controversial than rivers and harbors work since their immediate importance to the war effort was not so easily discerned, and even though the number of flood control projects was fewer, the cost per project was far more.

The 1942 *Annual Report of the Chief of Engineers* confidently advised, "All authorized flood-control projects are directly connected with the national economy and are therefore either directly or indirectly related to the war effort, especially when it is remembered that one major flood in a large river basin, such as the Ohio or Mississippi, may easily accomplish in a few weeks at least the same amount of damage that can be caused by intensive air raids." The Corps emphasized, "All of these [flood control] projects are parts of comprehensive coordinated plans for the river basins of the Nation to provide desirable and economic flood protection and allied benefits for a large number of centers of industry and population and for many thousands of acres of rich agricultural land." The importance of these projects notwithstanding, the *Annual Report* noted that flood control projects initiated before the war "have been and are being brought to completion or to a safe point of suspension as soon as possible."

Indeed, the War Production Board ordered the Corps to suspend 35 flood control projects and curtail 32 others. In many cases, the Corps was able to stop work at a point when the uncompleted structures still offered substantial flood

Troops of the 398th Engineer General Service Regiment detrain at Biscoe, Arkansas, to replace the 359th Engineer General Service Regiment fighting the White River flood.

protection. Contracts were suspended without formal termination, which allowed work to begin again at short notice.

The Corps' continued assertion of the importance of flood control projects to national defense, while responding to presidential directives to reduce flood control expenditures, suggests a certain amount of possibly unavoidable bureaucratic schizophrenia. The Flood Control Act, signed on 18 August 1941, authorized 64 projects "in the interest of national security and the stabilization of employment" which were to be "prosecuted as speedily as may be consistent with budgetary requirements, under the direction of the Secretary of War and the supervision of the Chief of Engineers."

However, President Roosevelt directed that no new projects be begun unless they were of direct importance to the defense of the nation. In fact, in fiscal year 1942, only seven new flood control projects were initiated, mostly to supply power to war industries or to protect industrial centers against floods. Included were the Berlin Reservoir project to protect the steel industries in the Mahoning Valley, Ohio, and to supply water; projects in Tulsa, Oklahoma, and Prattville, Alabama, to protect war-related industries; and, at the request of the War Production Board, three multipurpose

dams to augment power production. Altogether, in fiscal year 1942, the Corps worked on 41 dam and reservoir projects, putting 14 into operation, and on 91 local flood protection projects, completing 17 of them. Some projects, such as Bluestone Reservoir in West Virginia and Youghiogheny Reservoir in Pennsylvania, were not brought "to a safe point of suspension" for another two years.

In 1943, the Corps initiated construction of a local flood control project on the Illinois River at East Peoria, Illinois, in order to protect a Caterpillar Tractor plant; the Mosquito

Civil Works Expenditures
Fiscal Years 1941-1945
(in millions)

	1941	1942	1943	1944	1945
Rivers and Harbors					
New Work	45.9	44.6	37.0	26.1	6.9
Maintenance	40.6	44.1	47.3	38.3	50.3
Total	**86.5**	**88.7**	**84.3**	**64.4**	**57.2**
Flood Control					
New Work	90.3	84.7	93.5	58.8	25.9
Maintenance	3.4	3.2	4.1	13.6	13.7
Total	**93.7**	**87.9**	**97.6**	**72.4**	**39.6**
Mississippi River and Tributaries					
New Work	26.8	18.7	14.1	16.9	23.0
Maintenance	3.8	7.8	11.5	12.0	11.0
Total	**30.6**	**26.5**	**25.6**	**28.9**	**34.0**

Note: Expenditures do not include Sacramento River flood control, working funds transferred from other departments, and miscellaneous funds allocated for National Industrial Recovery Act, Public Works Administration, Civil Aeronautics Administration, and District of Columbia projects.

Civil works expenditures.

Creek Reservoir to supplement the Berlin Reservoir in the Mahoning Valley; and a project on the Teche and Vermillion rivers of Louisiana to protect important rice production areas. Additionally, the Corps had to perform emergency repairs after major flooding in 1943 and 1944. Throughout the war, the Corps continued to do flood control work to protect vital industries or agricultural lands. Because of the cost of these projects, new flood control work remained the largest single civil works expenditure throughout the war.

In spite of the requirement to reduce nonmilitary spending, the Corps was regularly under pressure to do all sorts of civil works during World War II, and not all the pressure came from Congress. The Army and the Navy regularly requested help from the Corps on various water projects, including some that had never been authorized. The Navy justified such requests by insisting that the work was necessary for the ship-building program, navigation safety, seaplane landings, bases for patrol or convoy vessels, or some other reason. The Corps consolidated requests from the military services or from the wartime Office of Production Management and sent a list to Congress through the Secretary of War with the recommendation that the projects be authorized.

More than that, knowing that President Roosevelt would question some of the projects, the Corps requested that its divisions around the country review cost figures and develop data that would make a "full and convincing defense" before Congress. Indeed, as early as the beginning of 1941, Colonel Ernest Graves, who worked in the Office of the Chief of Engineers, suggested that Corps districts and divisions provide a "sob story" for flood control projects coming before Congress in order to engender support. General Schley simply directed district engineers to supply "human interest" stories.

While not officially part of the civil works program, the Corps oversaw two special wartime projects related to rivers and harbors. Both projects were done for the Defense Plant Corporation. At Escanaba, Michigan, the Corps constructed two ore docks and appurtenant facilities in order to maintain the flow of iron ore from the mines to the steel plants. The Corps also constructed a fleet of vessels to barge essential commodities through the inland waterways system. The

program involved building 100 steel hull tugboats, 180 welded steel barges, 269 wooden and composite barges, 21 twin-screw steel hull towboats, and 2 oil terminals for water-rail transfer. This project cost about $85 million.

During World War II, the executive branch—mainly White House offices—came to assume increasing control over public works programs. This partly resulted from the continuing struggle of President Roosevelt to impose centralized planning and control over budgetary and planning matters. No matter that Congress did not fund all of the Bureau of the Budget's activities or that it rendered impotent the National Resources Planning Board. The fact of the matter was that the President's influence and popularity, coupled with his wartime powers, allowed the White House to assume policy-making functions that earlier had rested with Congress. The President's increased authority also resulted from congressional confusion. There was little agreement on what a "national defense" project was, and members tended to look to their own parochial interests and to the postwar period when jobs would be needed and the heated wartime economy might cool.

The Corps was just as confused. At about the same time that Corps officers protested that they were following the President's policy to the letter, they were seeking additional funding, suggesting new projects, and writing "human interest" stories. In December 1943, the River and Harbor and Flood Control Branch in the Construction Division of the Office of the Chief of Engineers became a separate Civil Works Division, with Colonel George R. Goethals in charge. By that time, the Corps was already at work planning postwar civil works projects. This activity was partly in response to a May 1943 presidential memorandum directing federal agencies to develop supplemental appropriation estimates covering the cost of updating public works plans so that work could be started quickly once war ended.

Roosevelt also requested agencies to recommend legislative changes that would expedite postwar construction. Roosevelt's intuition was right. There was a postwar public works construction boom, and the Corps' civil works projects expanded enormously. Indeed, the 1944 Flood Control Act, passed in December of that year, authorized the appropriation

of $750 million for about 150 new projects. It also gave the Corps new authority to develop and operate recreation facilities and to dispose of hydroelectric power not needed for project operations.

Although the war had given the Corps a major new responsibility for military construction, neither during nor after the war did the new mission diminish the Corps'—or the nation's—commitment to water resources development.

Sources for Further Reading

An important work that criticizes the Corps for its lack of administrative accountability is Arthur Maass, *Muddy Waters: The Army Engineers and the Nation's Rivers* (Cambridge: Harvard University Press, 1951).

Lenore Fine and Jesse A. Remington supply some useful background material, but do not critically examine the relationship between the Corps' civil works and military construction missions. See their work, *The Corps of Engineers: Construction in the United States. United States Army in World War II. The Technical Services.* (Washington, DC: The Office of the Chief of Military History, United States Army, 1972).

The research collections of the Office of History, Headquarters, U.S. Army Corps of Engineers, has some informative sources including "War, Politics, and Public Works: The Impact of World War II on the Civil Activities of the Army Corps of Engineers," by Lee F. Pendergrass (unpublished); "The History of the Tennessee–Tombigbee Waterway," Volume I by James Kitchens (unpublished); the civil works legislative files; and the Arthur Maass papers.

Other sources include *The Annual Report of the Chief of Engineers* for 1939–1945; the Executive Orders of the President; and the *Report of the Federal Civil Works Program as Administered by the Corps of Engineers, U.S. Army,* Part I, Volume 3 of the 1951 *Annual Report of the Chief of Engineers.*

called the Pick–Sloan Plan, and an examination of its evolution illuminates wartime water resources politics.

Plans for the development of the Missouri River go back to the decades immediately following the Civil War. The most important study was the Corps of Engineers "308 Report," a 1926 study that provided cost figures for doing multipurpose surveys of the nation's navigable rivers. Congress published the report in House Document 308 and authorized the surveys in the 1927 Rivers and Harbors Act. In 1934, Captain Theodore Wyman, Jr., submitted a 1,200-page "308 Report" on the Missouri River, which identified numerous potential navigation, flood control, irrigation, and hydropower projects. Even before the report was completed, the Corps had begun work on Fort Peck Dam in Montana, a Depression Era emergency relief project to insure downstream navigation while providing hydroelectric power to the Upper Missouri basin.

In March 1943, rapidly melting snow in the Dakotas resulted in major flooding along the Missouri. Omaha, Nebraska, suffered the most. Congressmen from flooded districts introduced resolutions calling for yet another survey of the basin in order to prevent similar destruction in the future. The House Committee on Flood Control approved a resolution on 13 May that directed the Corps to prepare the new survey, just as another flood was cresting on the Missouri. Colonel Lewis A. Pick, Missouri River Division Engineer, was assigned the task in accordance with standard procedures. He completed his report in 90 days. Thirteen pages long, but borrowing heavily from the "308 Report," it proposed three groups of projects. The first group included 1,500 miles of levees on both sides of the Missouri stretching from Sioux City to the mouth of the river. The second group included reservoirs on the tributaries, and the third group called for five more dams on the main stem of the river.

On 31 December 1943, the Chief of Engineers, Major General Eugene Reybold, sent the Pick plan to the Bureau of the Budget. Included with the report were comments from various federal agencies. Generally, the Department of Agriculture and the Federal Power Commission supported the plan. Bureau of Reclamation Commissioner Harry W. Bashore was less enthusiastic. His detailed comments

address the 9-foot channel then being considered. In summary, the plan was not in accord with the program of the President.

Bureau of the Budget objections were not of much concern to the House Flood Control Committee. The very day that Smith returned the document to the War Department, the Committee opened hearings on the plan, even though the study had not been formally communicated to the legislative branch. This circumvention of the executive branch caused understandable anxiety among Corps officers, but Committee Chairman William M. Whittington assured them that "We will assume responsibility."

The plan, with Bureau of the Budget objections, was finally formally sent to the Flood Control Committee on 28 February. No sooner had Whittington begun the hearings than he ran into opposition from the Upper Missouri basin states. Governors Lester C. Hunt of Wyoming, Sam C. Ford of Montana, and John Moses of North Dakota insisted that the Pick plan and the 9-foot channel bill be considered together. As Ford put it, "The issues which disturb the Upper Missouri River basin states are so interwoven in the two bills that they cannot be understood or solved without consideration of some of the features of both bills." In short, upper basin representatives were adamant supporters of multipurpose development. A 9-foot channel would require more water from upstream, consequently threatening an adequate water supply for irrigation and other beneficial consumptive purposes.

President Roosevelt was sympathetic about the problem. He wrote Representative Joseph J. Mansfield, Chairman of the House Rivers and Harbors Committee, "In order to make it clear that the Congress intends to safeguard the upstream states against unreasonable withdrawals of water for downstream developments, I believe the bill should contain a definite declaration that the beneficial use of water in the upper basin shall not be affected by the proposed lower basin improvements."

The fundamental question was how to distribute the water equitably among the Missouri River states, but another issue nearly as controversial was the extent of federal authority to regulate navigable waters. Recent Supreme Court

decisions, especially *United States v. Appalachian Electric Power* (311 U.S. 377), had asserted a broad federal plenary power over navigable waters. The high court concluded that the Commerce Clause of the Constitution legitimately could cover related activities such as flood control, hydropower, and watershed development. More than that, in *State of Oklahoma v. Guy F. Atkinson Co.* (313 U.S. 508), the Supreme Court affirmed that federal jurisdiction over navigable rivers included headwaters and tributaries. These rulings appeared to negate long-standing state laws under which water had been appropriated and used for beneficial consumptive purposes. The actual or potential exercise of federal jurisdiction threatened traditional practice, throwing into question water rights throughout the Missouri basin. The situation was particularly difficult because federal navigation powers were even more firmly rooted in the nation's history than were state water laws.

The House Flood Control Committee acknowledged the concerns of the upstream states and recommended that no new demands be made on the river's water and that some planned main stem storage be transferred to tributary sites. Then the bill was reported favorably to the full House. The House proceeded to approve both the 9-foot channel bill on 22 March and the Pick plan on 9 May 1944. Upper basin interests thereupon turned their attention to the Senate, where the western states traditionally enjoyed more power, especially on water matters.

Senator Joseph C. O'Mahoney of Wyoming led the fight in the Senate on behalf of the upper basin states. He was an avid proponent of national planning and multipurpose water development. Four days before the House passed the Pick plan bill, O'Mahoney introduced into the Senate the long awaited Bureau of Reclamation plan for the development of the Missouri basin.

The bureau had been working on the plan since 1939, but expedited it after Pick produced his proposal. The man in charge of the survey was W. Glenn Sloan, assistant director of the bureau's office in Billings, Montana. Sloan's plan was intended to be comprehensive and to address all the various beneficial uses of water in the basin. It's philosophy was utilitarian: "The greatest good to the greatest number."

W. Glenn Sloan and Major General Lewis A. Pick.

The bureau assumed that farming would remain the primary regional economic base and recommended doubling the amount of irrigated land, adding 4.76 million acres to the 4 million already being irrigated, and supplying supplementary water to another 5.47 thousand acres. Sloan also proposed building 17 power plants to generate about 4 billion kilowatt-hours annually. He rejected the Corps' recommendation to build a dam at Garrison on the main stem and instead proposed that more dams be built on the headwaters. The plan called for 90 dams in all. He did concede that his plan would reduce navigation water at Sioux City "by somewhat less than half the original stream-flow" but thought the allocation of water between navigation and irrigation was a political decision better left to Congress.

The two plans, Pick's and Sloan's, were subjects of much discussion and critical analysis in the Missouri River basin in the summer and fall of 1944. Only the war itself stimulated more interest. Within Congress, the House Flood Control Committee considered the Pick plan, while the Rivers and Harbors Committee debated the 9-foot channel project. The Senate Commerce Committee considered both the Pick and Sloan plans. Since the Sloan plan was formally presented only a few days before the House Flood Control Committee endorsed Pick's plan, the Sloan plan received only a cursory overview on the House side, although some highlights had already been presented in committee hearings. When O'Mahoney presented the Sloan plan to the Senate Commerce Committee, the Bureau of the Budget had not decided whether the plan was or was not in accord with the program of the President. Therefore, the bureau withheld advice in this regard. Secretary of the Interior Harold Ickes thought the Army and Bureau of Reclamation plans could

be reconciled. The Corps of Engineers, however, promptly took issue with the bureau's proposal to construct flood control dams far upstream. The agency also thought it unwise to construct the Missouri–Souris diversion, a large-scale irrigation project, before the other needs of the basin were satisfied.

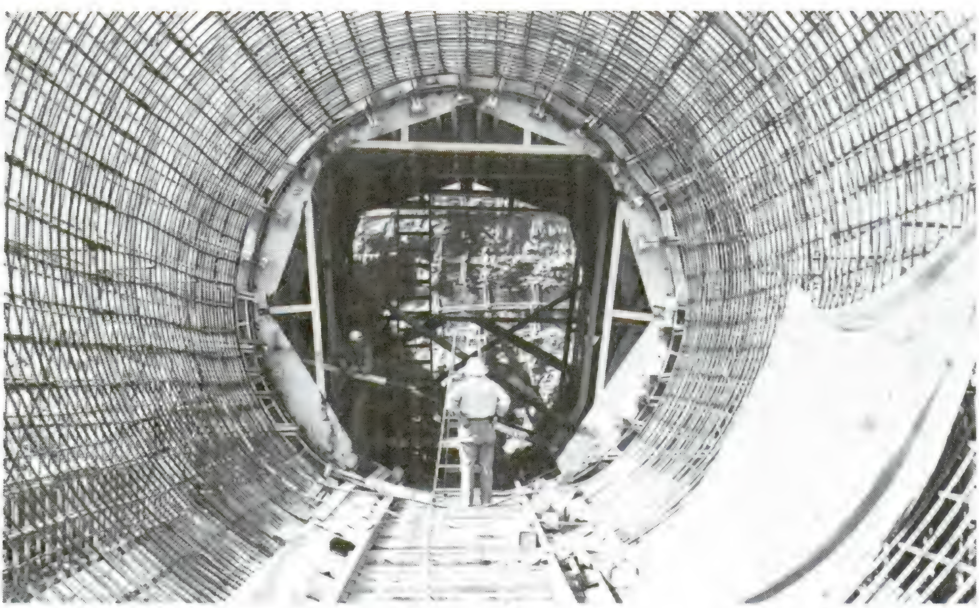
As debate continued, western senators became increasingly anxious that their states have the opportunity to participate in the planning for the Missouri River basin and that some general policy be established on water priorities in the region. Along with Senator Eugene Millikin of Colorado, Senator O'Mahoney introduced several far-ranging amendments to the legislation being considered by the Senate Commerce Committee. These amendments were put into final shape at a water conservation conference held in Chicago on 7–8 September 1944. The major organization at the conference was the National Reclamation Association. In summary, the reworked amendments:

- Recognized the interests and rights of states in determining the development of watersheds within their borders.
- Required that federal water resources plans be reviewed by the affected states.
- Established that domestic, municipal, stock water, irrigation, mining, and industrial uses of water in arid regions (west of the 98th meridian) of the Missouri basin have priority over downstream navigation uses.
- Authorized the Secretary of War to make contracts with public and private concerns for domestic and industrial uses of surplus water in flood control reservoirs.
- Authorized the Secretary of the Interior to build reclamation works to utilize surplus water from flood control reservoirs for irrigation projects.

More implicitly, the Chicago conference dealt with another issue that unsettled many Missouri basin politicians. It was the idea of establishing a Missouri Valley Authority (MVA) along the lines of the Tennessee Valley Authority (TVA), which would exert some sort of centralized control over the basin's development. Senator James Murray of Montana introduced the first MVA bill on 18 August 1944. It closely followed the TVA act of 1933. Five days later Iowa Senator

Guy Gillette introduced another MVA bill; similar bills followed in the House and Senate over the next month. President Roosevelt predictably threw his support behind the legislation. Within the Missouri River basin, the St. Louis *Post Dispatch* trumpeted the virtues of the MVA, and the National Farmer's Union (claiming as members some 141,000 farm families within the basin) threw its weight behind the legislation. On the other side, most officials, particularly those from the upper basin, opposed the idea, fearing loss of control of their own destiny and disliking "big government" in general. When the Chicago conference approved amendments that empowered the Secretary of War or Secretary of the Interior to do certain things, it was not only endorsing priorities, but also the traditional federal structure. State governors wanted to continue to work with the Corps of Engineers and the Bureau of Reclamation, and not with some new organization that would be insulated from the political process.

In Chicago, the politicians decided on overall priorities and procedures, but it was left to the agencies to develop a final compromise plan. This was done in Omaha, Nebraska, on 17–18 October 1944. An interagency group, headed by



The Oahe Project, Pierre, South Dakota, was a major main-stem project of the Pick–Sloan Plan to regulate the waters of the Missouri River. This 1955 view of the interior of the conduit section of downstream portal #6 shows the reinforcing steel in place. *(Omaha District, Corps of Engineers)*

Sloan for the Bureau of Reclamation and Brigadier General R. C. Crawford for the Corps (Pick had been sent to Burma to supervise the construction of the Ledo Road), hammered out a one-page agreement.

The understanding covered questions of jurisdiction and the works to be constructed. The Corps would design the main stem reservoirs and determine storage requirements for flood control and navigation in other multipurpose projects. The bureau would determine irrigation capacities for reservoirs on both the main stem and the tributaries, and both agencies recognized the importance of the "fullest development" of hydroelectric power, consistent with the development of other beneficial uses of water. The bureau's 27 reservoirs on the Yellowstone replaced the Corps' two large dams, and the bureau's plan for a large reservoir at Oahe replaced the low-level dam proposed by the Corps. Finally, the bureau and the Corps reconciled their plans for the Republican River headwaters. With some minor modifications, all the rest of the elements of both plans were accepted, including the Corps' controversial dam at Garrison on the main stem. On 27 November, President Roosevelt sent this agreement to Congress, but again appealed for the establishment of a MVA to oversee the basin's development.

Senator John H. Overton of Louisiana, who chaired the subcommittee considering the flood control and rivers and harbors bills, chose to endorse the Bureau of Reclamation/ Corps of Engineers agreement and the revised O'Mahoney–Milliken amendments as well, and he urged the Senate to approve the package without delay. In response, the compromise and the amendments were included in the Flood Control Act of 1944, which passed Congress on 1 December. Overton did not allow the MVA legislation to get out of the subcommittee, and he postponed the bill authorizing the 9-foot channel below Sioux City until the following year; it was routinely passed in March 1945 as part of the regular Rivers and Harbors Act. The "reconciliation" that had occurred the previous October offered the hope to rivers and harbors interests that there would be sufficient reservoir capacity for navigation regardless of irrigation and other demands.

Out of the debates on the Pick–Sloan Plan came legislation that shaped the development of the entire Missouri River

The Fort Randall Reservoir, on the Missouri River at Pickstown, South Dakota, was a major feature of the Pick–Sloan Plan. This aerial view, looking upstream, shows the nearly completed dam in 1955.
(Omaha District, Corps of Engineers)

Valley and literally transformed the landscape of America's heartland. Today, a glimpse at the map reveals the scores of dams, levees, and other water resources projects that are part of the Pick–Sloan Plan. However, these debates affected more than the Missouri River basin. Western concerns that states be offered the opportunity to review federal reports and that state interests be recognized became requirements that applied to the entire country. The subordination of navigation to beneficial consumptive uses applied to all states "lying wholly or partly west of the 98th meridian" and not just to states in the Missouri River basin. The specific authorities given to the Secretary of War to make contracts for the use of surplus waters and to the Secretary of the Interior to market hydroelectric power also are nationwide.

Thus, the December passage of the Flood Control Act of 1944 marked an important step in the evolution of water resources policies and projects. The events surrounding the development of the Pick–Sloan Plan belie the conventional image of a nation at war, putting aside peacetime activities to focus on winning the military struggle. The fact is that a great deal of attention was paid to potential postwar public works projects. As early as the spring of 1943, President Roosevelt had instructed executive agencies to prepare

for postwar activities. The more surprising aspect of the continued interest in water resources development is that plans and policies were not simply dusted off and made ready for use, but that, while engaged in a titanic military struggle, the United States made fundamental and lasting changes in civil works policies and procedures.

Sources for Further Reading

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The Federal Engineer: Damsites to Missile Sites. A History of the Omaha District U.S. Army Corps of Engineers (nd) has a chapter on the Pick–Sloan Plan which is generally correct but has some minor inaccuracies and omissions.

Missouri River Division Historian John Ferrell has written a draft history of water resources development in the Missouri River basin entitled "Big Dam Era." It is comprehensive and concentrates on the formation and relationship of upper and lower basin blocs and coalitions.

War in the Heartland: The St. Paul District

by John O. Anfinson

No Corps of Engineers district lay farther from the battlefields of World War II than the St. Paul District. Still, this district contributed to the country's war effort. Shifting from civilian to military projects, the district helped build ammunition plants, airport runways, and small assault boats. It provided navigable channels on the Mississippi and Minnesota rivers, relieving overburdened railroads and allowing for the transport of essential commodities.

One of the St. Paul District's most important contributions was the construction of a small arms ammunition plant. In response to Germany's invasion of Denmark, Norway, the Low Countries, and France in the spring of 1940, President Franklin D. Roosevelt sought to increase the size of the country's Army and its production of munitions. Consequently, the Army initiated a wave of ammunition plant construction. During the winter of 1940–41, as the Allies' situation became more desperate and the threat to America increased, rearmament became more critical. The need to supply the Allies with ammunition became paramount, and President Roosevelt called for the United States to become the "Arsenal of Democracy." Congress supported this call with the Lend–Lease Act of 1941. This act led to a second wave of munitions plant construction. The Army located one of the new plants, called the Twin City Ordnance Plant (now known as the Twin Cities Army Ammunition Plant), near New Brighton, Minnesota, a northern suburb of St. Paul. It planned to make this plant "one of the world's largest suppliers of .30-caliber and .50-caliber shells."

Initially, the Army assigned plant construction to the Quartermaster Corps and plant management to its Ordnance Department. A prime contractor was to superintend plant design and operation. On 14 July 1941, the Army signed a contract with the Federal Cartridge Corporation as the prime

contractor. The corporation was to subcontract for the design and engineering of the plant and its equipment and construction with subcontractors chosen by the Quartermaster General.

Before choosing Federal Cartridge, the Army had begun planning for the project and had examined a number of sites for the plant, preliminarily selecting one site. The Quartermaster Corps, in charge of military construction at this time, assigned Lieutenant Colonel Joe S. Underwood command of the plant's construction. Arriving on 17 July 1941, Colonel Underwood agreed that the site selected—a 2,425-acre site 8 miles north of the Twin Cities—would be best. Farmers, proprietors and residents who lived on the site had to leave by 4 August.

On 15 August 1941, the subcontractors moved equipment to the grounds and began building temporary buildings. Thirteen days later, the Army held a ground breaking ceremony with Major General Eugene Reybold, Chief of Engineers, Minnesota Governor Harold Stassen, and Representative Melvin Maas the principal speakers. "Across the two ocean-highways to our shores comes the lightning flash of war to arouse us from our double decade of delusion," said the Chief, emphasizing the urgency and importance of the ammunition plant. Based on the record of construction at other plants, he estimated that the Army would not receive ammunition from the Twin Cities plant until September 1942.

A large work force soon invaded the area. By 1 October, construction occupied 4,676 workers, and two months later, 11,102 workers, laboring six days per week, 24 hours per day, swarmed over the plant site. By the end of December, the number of construction workers peaked at 11,224.

The Japanese attack on Pearl Harbor on 7 December changed operations at the ammunition plant. The purpose and urgency of the workers' tasks assumed new meaning. An ordnance plant narrative observed that the attack "transformed. . .[the plant's] identity overnight into a vital war industry." The next day construction work on the plant went to seven days per week, 24 hours per day. On 15 December, the Army transferred the Quartermaster Corps construction director, Captain Lynn C. Barnes (who had replaced Colonel Underwood on 2 November), his staff, and the construction

Major Lynn C. Barnes (far right) inspects work at the Twin Cities Ordnance Plant.

mission at the plant to the St. Paul District of the Corps of Engineers. Captain Barnes became the area engineer.

When the St. Paul District took over construction, nearly all the principal buildings had been enclosed. But work on the plant was far from complete. Under the district's supervision, workers finished the first permanent structure, the administration building, on 31 January 1942, and the Ordnance Department headquarters and plant management staffs moved into the building.

With America's entrance into the war, the Army decided to double the plant's production capacity by constructing two additional .30-caliber buildings, one .50-caliber building, and the structures necessary to support this increased production. Unlike the brick, steel and concrete buildings of Plant I, the new plant, known as Plant II, had to be constructed on a "critical material and bare necessities" basis. This meant that the Corps constructed most buildings of wood. Construction on this phase began on 10 June 1942.

By the summer of 1942, the Army had determined that it needed more .50-caliber incendiary ammunition and had

decided to add to the plant another building with a capacity to produce 750,000 rounds per day. The new production building required the design and construction of 15 support buildings. This phase of construction became known as the Plant II Expansion. On 30 December 1942, Congress authorized the construction of additional buildings for the expansion of Plant II. The addition of Plant II, Plant II Expansion, and changes in ammunition design required adding to and remodeling some buildings in Plant I.

Despite the new work and modifications required, nearly all the major construction work had been completed by 15 January 1943. The St. Paul District, however, continued to oversee the construction of new buildings and building modifications until the end of the war. In 16 months the Army had constructed 323 buildings, a 1-million-gallon water reservoir, and one water treatment plant of 300,000 gallons per hour capacity (reducing water hardness to zero); had laid 21.7 miles of bituminous surfaced roads, 9.8 miles of bituminous surfaced walkways, 15.6 miles of railroad tracks,

Brick laying at the Twin Cities Ordnance Plant.
(St. Paul Pioneer Press, *26 October 1941)*

31.3 miles of sewer line (sanitary and storm), 21.4 miles of water distribution lines, 14.1 miles of gas mains, and 16.8 miles of steam distribution lines; and had strung 28.9 miles of electrical wires and 11.1 miles of telephone lines. Construction costs (including design engineering, inspection and installation of production equipment) equaled $43,409,923, and production equipment costs came to $27,230,730.

According to Lieutenant Colonel John H. Hinrichs, the plant's commander, the "construction time and the time it took to get into production is recognized by the Army as a record." Well ahead of General Reybold's prediction, the production of .30-caliber shells started on 5 February 1942, and on 9 March the Ordnance Department accepted the first .50-caliber shell produced at the plant. On 31 March, the Ordnance Department loaded 48,000 rounds of .30-caliber shells onto waiting trucks, which hauled them to the Northwest terminal in Minneapolis for shipping by rail to the Milan Ordnance Depot at Wolf Creek, Tennessee. In its first ten months, the plant produced 684,536,400 rounds of ammunition. In August alone, the Ordnance Department accepted 119,367,900 cartridges, and in December 128,809,600 rounds. In constructing the Twin Cities Ordnance Plant, the St. Paul District made a quick and significant contribution to the Allied war effort.

The district also contributed to the nation's war effort by building hundreds of small wooden vessels for the crossing of the Roer River for the invasion of Germany. When, in February 1944, the Army asked the St. Paul District if it could build hundreds of small assault boats, the district engineer responded within half an hour that it could, "if Washington would guarantee the supply of waterproof plywood." Each boat was to be 16 feet long and carry eight soldiers.

Franklin Ryder, a district retiree, recalls that a local boatworks built the boats under contract. The project, he said, was hush–hush—one did not talk about the boatworks in the office. The district loaded the boats on trucks (under armed guard) and took them directly to Wold Chamberlain Airfield in Minneapolis and loaded them onto planes. After leaving Minneapolis, the planes refueled at Gander, Newfoundland,

and continued on to Europe. The Army used the boats "with limited effectiveness" to cross the Roer River in February 1945.

The St. Paul District also supported the war effort in an unexpected way. In 1943, the Cargill Corporation received two Defense Department contracts to build 18 ocean-going tankers at their shipyard, 13 miles up the Minnesota River at Savage. The tankers measured 315 feet in length. Congress, however, had authorized only a 4-foot channel for the Minnesota River. On 27 March 1942 local interests requested the Corps to extend the 9-foot channel to the Cargill shipyard and dredge a launching basin there. On 17 April, the Secretary of War, under authority of Section 4 of the Rivers

American Oil and Gas tanker built at Cargill Corporation on the Minnesota River. *(Frank Ryder)*

and Harbors Act of 4 March 1915, and with an initial contribution of $60,000 from the local interests, approved the request. The district began dredging on 3 August 1942, and the first tanker started downriver to New Orleans on 6 November 1943. In addition, in 1942 a St. Paul boatworks built a 110-foot sub-chaser that sailed the river to New Orleans. These ships were among the nearly 1,000 vessels built on the nation's inland waterways for the Navy and Coast Guard.

Another Corps project allowed the United States to move these ships on the Upper Mississippi River. Between 1933

and 1940, the St. Paul District, with the Rock Island and St. Louis Districts, constructed 23 locks and dams from above Red Wing, Minnesota, to near St. Louis, Missouri, and modified three existing locks and dams. These structures, comprising the Upper Mississippi River 9-foot channel project, established a deep-draft channel from Minneapolis to St. Louis. Some advocates of the project had claimed that it was necessary to national security. They warned that the nation's coasts might not be safe during another war and that shipping on the inland waterways would become essential. They did not know how quickly their argument and the Corps' project would be tested.

Traffic on the Upper Mississippi River had declined throughout the early 20th century and had nearly died in the mid-1920s. It climbed slowly during the 1930s as the Corps finished the 9-foot channel project. Tonnage grew from 1.7 million tons hauled in 1933, when construction began, to 2.6 million tons in 1938, when the St. Paul District completed its segment of the project, and to 3.5 million tons in 1940.

With the completion of the 9-foot channel project on the Upper Mississippi River, the St. Paul District and the waterway shipping industry confidently approached their roles in meeting the transportation demands created by World War II. Some transportation observers saw indications of a transportation boom even before the United States entered the war. In September 1941, the *Upper Mississippi River Bulletin* reported that the war in Europe was increasing waterways shipping in the United States. While railroads handled most of the new tonnage, displaced shippers began turning to the waterways.

River traffic increased slowly, however, and no boom occurred until after the United States entered the war. Even then, the Mississippi River did not receive all the business shippers had hoped for. In March 1943, *Business Week* reported that, while rivermen had been waiting for a surge in demand, railroads had been meeting all the war emergencies.

Several factors accounted for the river's slow start. During the war, especially in its early years, speed outweighed cost. Consequently, most war-related manufactures traveled by rail. As many industries shifted to war-related production,

commercial production declined, and the commodities available for shipping on waterways decreased. *Business Week* warned that as long as nonwar production declined, shipping on inland rivers also would fall. The loss of experienced waterways laborers to the war effort also hindered inland waterways shipping. By March 1943, the labor shortage had become so severe that the War Manpower Commission reminded draft boards to give occupational deferments to inland waterways workers. The great quantity of goods handled by barges occasionally limited their use, also. Some plants lacked storage facilities for barge-load quantities. In addition, many key war production facilities were located away from waterways, and cargoes had to be transferred to trains or trucks for delivery to the plants. As the government counted goods in transit as inventory, the large quantities tied up in slow-moving barges created other problems for manufacturers. River cities reported that, as wartime control of essential commodities became more stringent, some companies paid the higher rates of rail shipment "to hold down total inventories and boost working inventories." Despite these problems, traffic on the upper river increased during the war.

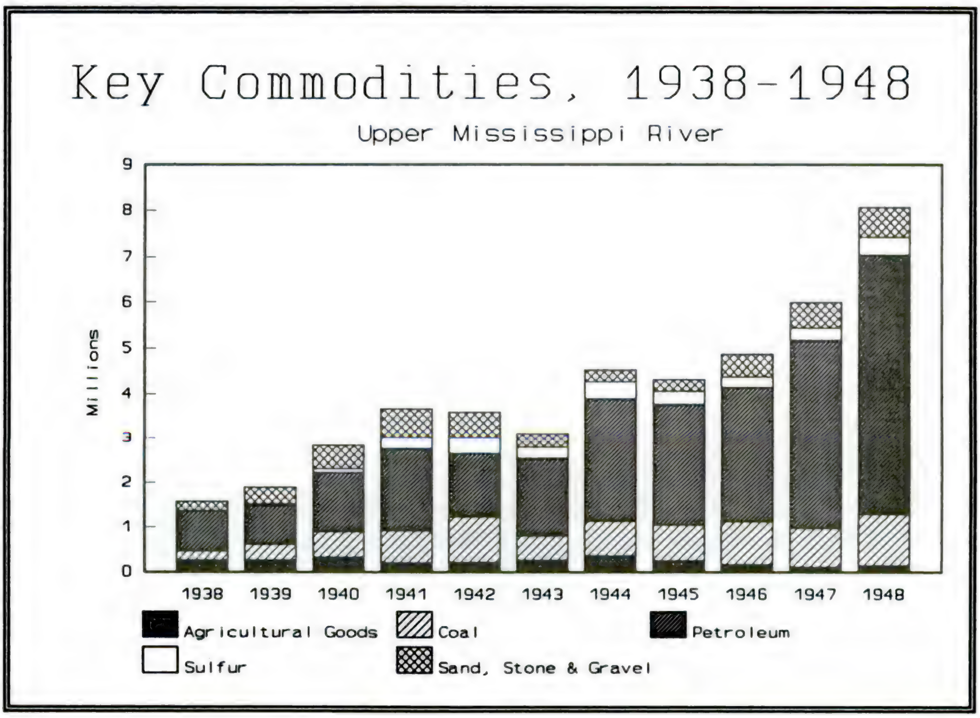
German submarine attacks on shipping off the East and Gulf coasts during the first seven months of 1942 boosted waterways transportation. With no more than a dozen submarines, the Germans attacked 285 ships off the East and Gulf coasts, sinking 248 and damaging 32. Five ships escaped. In March alone, the Germans sank 28 ships, totaling 159,340 tons, off the East Coast and another 15 ships, of 92,321 tons, in the Gulf and Caribbean. Tankers comprised over one-half of the ships sunk in this month. The Germans had recognized that they could cripple the Navy's Atlantic fleet and disrupt American civilian life by cutting off oil shipments to the East Coast, and they successfully did so.

As ocean-going tankers from the Gulf of Mexico, Venezuela, and the Dutch West Indies provided most of the fuel oil and gasoline for the East Coast, the German submarine campaign caused an acute shortage of these commodities. To supply the East, the United States turned to railroads and inland waterways. While railroads hauled the majority of the petroleum, waterways made a vital contribution. The Lower Mississippi River and its eastward-branching tributaries

directly benefitted from shortages along the Atlantic seaboard. The Upper Mississippi River indirectly profited; as the oil shortage demanded more railroad cars, more oil and other goods had to be shipped by water to the Upper Midwest.

For this reason, oil and oil products (fuel oil, kerosene, and gasoline) became even more important to shipping on the Upper Mississippi River than they had been before the war. Comprising from 35 to 40 percent of the upper river traffic, petroleum products grew to nearly 60 percent by the end of the war. By the end of 1943, approximately 90 percent of the fuel oil for the Twin Cities arrived in barges. Most of it came from the Wood River Refineries across from St. Louis, and the remainder from refineries in southern Louisiana. The Twin Cities used some 110 million gallons of fuel oil each year. In addition, about 25 to 30 percent of its gasoline arrived in river barges.

River boosters argued that oil shipping on the waterways made a great contribution to the war effort. It kept industrial plants operating on the East Coast and in the Midwest, it kept combat training planes flying, and it kept people from



Mississippi River key commodities, 1938–1948.
(Annual Reports, Chief of Engineers, 1939–1949)

freezing. The German submarine campaign had justified the river boosters' argument about the importance of inland waterways transportation to national security.

German submarine attacks on eastern seaboard shipping also affected the transportation of sulfur and coal. Sulfur was a key element in the production of munitions, wood pulp, and rubber. As the East Coast took rail cars that could have been used for shipping sulfur to the upper Midwest, sulfur movement on barges increased. Before 1941, barges moved under 100,000 tons of sulfur annually on the upper river. Between 1942 and 1945, however, they carried 200,000 to 300,000 tons, all upbound. Coal movement increased dramatically on the Upper Mississippi River during the first year of the war, declined as dramatically the next year, and then rose again during the last two years of the war. By 1943, barges delivered about 600,000 tons of coal—used mostly by power companies—to the Twin Cities.

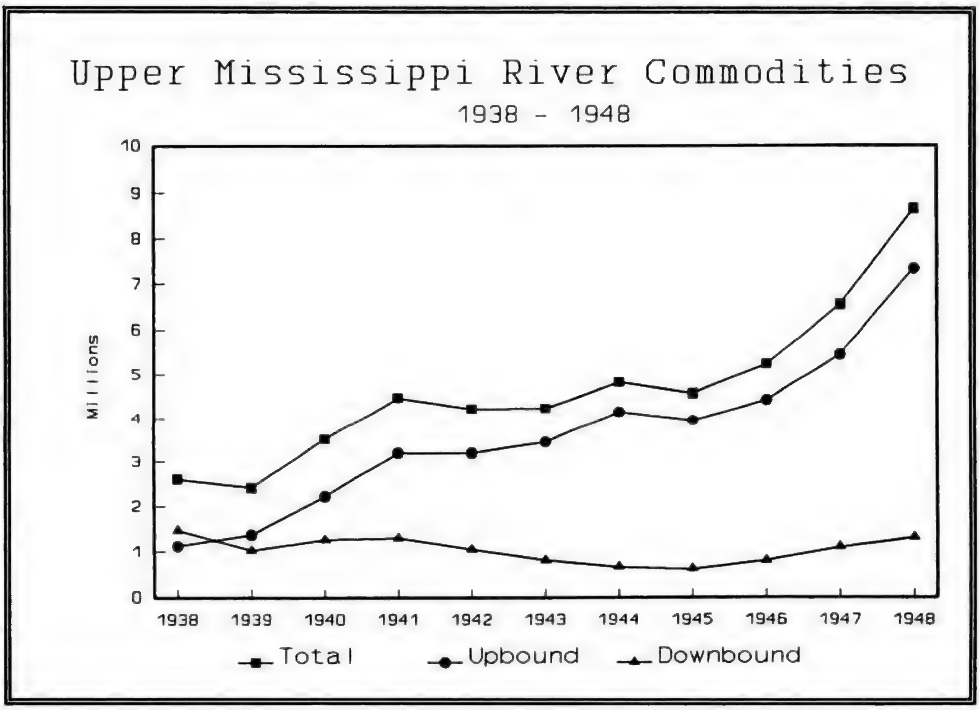
While the war increased world demand for American agricultural production, some upper river observers complained it also closed export markets and created a shortage of ocean-going vessels. Both problems, they charged, limited grain shipping. Although agricultural products were among the most important goods shipped downstream before and during the war, agricultural producers had not yet turned to the river as a major alternate to railroads. Given world demand, agricultural shippers used the rail system even more exclusively during the war.

While Americans produced much more corn than wheat, they exported only 20 percent of the corn compared to about 75 percent of the wheat. Still, corn led agricultural commodities shipped on the upper river, accounting for over 70 percent of all agricultural products in the years immediately before the war. Corn shipping, however, declined steadily before and during the war. In contrast, shipments of wheat, oats, barley, rye, and soybeans generally increased in the years before the war and continued to rise during it. In 1944, grain exports from New Orleans tripled over the previous three years, demonstrating a recovery in the movement of agricultural goods on the river.

The war caused or furthered many important changes in shipping on the upper river. Sand, stone, and gravel

shipments declined markedly during the war and rebounded soon after it ended. Shipments of iron and steel (ore and manufactured products) also declined during the war and rose again once it was over. Iron and steel commodities—raw as well as finished—had been essential to the war and moved by rail rather than on the slower barges. While oil products had been important downbound commodities before the war, the war curtailed their movement in this direction. Nevertheless, they remained among the most important products shipped down the river.

One change often cited by river watchers was the increasing imbalance of traffic going upstream versus downstream—"the river man's bogey," as one writer called it. On the Upper Mississippi River, downbound and upbound traffic were about equal during most of the 1930s. After 1938, however, downbound traffic declined and did not begin increasing again until the war ended. Upbound traffic surpassed downbound shipping in 1939 and increased steadily thereafter, dipping slightly as the war drew to a close in 1945. Three commodities accounted for the great increase in upbound traffic:



Upper Mississippi River commodities, 1938–1948.
(Annual Reports, Chief of Engineers, 1939–1949)

petroleum, coal, and sulfur. Together, these commodities comprised 78 to 91 percent of upstream traffic. Oil alone represented 35 percent in 1942 and had reached nearly 65 percent by the end of the war.

Other factors besides the war increased upbound traffic. The availability of the 9-foot channel encouraged oil and coal shippers to use the river before the war started. Oil companies had been exploring the establishment of terminals in the Twin Cities since 1937. Yet, the war hastened the use of the river by oil companies and other shippers of bulk commodities. The scarcity and expense of rail transportation forced these shippers to use the river with less of a trial than they may have wanted.

While German submarine activity diverted oil and other goods to the nation's inland waterways, the war limited shipping expansion on those waterways. Not only did the Midwest relinquish oil barges for use in the East, but it gave up dry cargo steel barges for conversion to oil barges. During 1942, barge operators sacrificed 116 steel barges for conversion to oil carriers. Steel shortages prevented shippers from building replacement barges. During America's first year in the war, barge operators on the Ohio and Mississippi rivers reported that traffic demands would exceed capacity by over 1 million tons.

Late in 1942, the War Production Board authorized $50 million for construction of barges and tugboats. While the new boats were for use on the lower river and coastal waterways, the board expected that their operation on these waterways would reduce stress on the upper river's fleet and release railroad tank cars to the Midwest. Minnesota Senator Henrik Shipstead hoped that the new barges would relieve the Eastern crisis "enough to eliminate the danger of arbitrary removal of upper river transport equipment, which Minnesota needs to maintain its own supplies of fuel," and prevent an oil shortage in Minnesota during the winter of 1943.

The Upper Mississippi River's 9-foot channel project allowed the Midwest and the St. Paul District to make a greater contribution to the war effort than they could have made without it. It provided the channel depth required to float ocean-going ships to New Orleans. It enabled the

Midwest to ship out and receive essential commodities such as grain, oil, sulfur, and coal, and eased railroad congestion. It proved its value to the nation's security. Few Corps projects receive such strenuous testing so soon after construction, and few projects so quickly justify their existence.

Sources for Further Reading

Raymond Merritt, *Creativity, Conflict & Controversy: A History of the St. Paul District, U.S. Army Corps of Engineers,* (Washington: U.S. Government Printing Office, 1979), is the best source for general information about the district's missions during the war.

To understand the role of the Mississippi River during World War II, readers should go to *The Waterways Journal* and the *Upper Mississippi River Bulletin.*

Other publications such as *Fortune Magazine* and *Business Week* offer good insights on the river's contribution to the national economy.

For good accounts of how the German submarine campaign off the American coast during the war's early years affected coastal and inland waterways shipping, see Captain S. W. Roskill, *The War at Sea, 1939–1945*, (London: Her Majesty's Stationary Office, 1956), and Homer H. Hickman, *Torpedo Junction: U-Boat War off America's East Coast, 1942*, (Annapolis, Maryland: Naval Institute Press, 1989).

Joseph R. Rose, *Wartime Transportation*, (New York: Thomas Y. Crowell Company, 1953), provides an excellent account of wartime shipping in the United States.

No substantive secondary accounts of the Twin Cities Ammunition Plant have been written. Those interested in this subject must consult the primary records held by the plant.

Mobilizing the Waterways: The Mississippi River Navigation System

by Michael C. Robinson

The Mississippi River and its navigable tributaries have been a bulwark of national economic expansion and defense since the 18th century. During World War II, this vast navigation system proved an important strategic asset. Prewar mobilization planners drew from the World War I experience when the waterways averted a transportation catastrophe by relieving the country's overburdened railroads. Faced with calamity, various federal government agencies struggled to awaken a dormant waterways industry, stimulating a revival of river commerce and newfound awareness of its role in national defense. The next two decades witnessed concurrent and reciprocal federal investments in river improvements and waterborne commerce. Consequently, after Pearl Harbor the Mississippi River navigation system facilitated home-front industrial mobilization as well as victory abroad. The war years also reshaped and strengthened inland navigation, setting the stage for subsequent peacetime growth.

The Lower Mississippi River served as the trunk of a tree-like navigation system that extended into the heart of the nation. By the onset of World War II, this waterway network was highly regulated and developed. On the great stream's main stem, some seven decades of Corps river engineering had transformed the unruly, meandering giant into a relatively safe transportation artery. In its natural condition, the Mississippi featured sandbars, snags, and split channels that claimed hundreds of antebellum steamboats. However, by 1941 channel stabilization measures such as bank protection, dikes, and maintenance dredging sculpted and fixed reliable channels far different than in the days of Mark Twain.

Congress authorized the Corps to remove snags from the river in 1824, but the transformation of the Mississippi began

a half century later. In the 1870s, improving the mouth of the Mississippi for oceangoing ships became a great national issue. Dredging efforts by the Corps failed, so it proposed building a ship channel that would reroute the deep-draft traffic into and out of the river. James B. Eads, a brilliant civilian engineer, offered another approach. He proposed to build jetties in one of the passes and allow the river to scour out a deeper channel. The Corps attacked his plan, but Congress accepted Eads' vision because he agreed to work on a "no cure, no pay" basis. The jetties succeeded, and by June 1879 a 30-foot depth existed in South Pass that stimulated a bold federal approach to addressing the river's other navigation and flood hazards. Concurrent with the successful completion of the jetties project, Congress established the Mississippi River Commission (MRC) and charged it with creating a comprehensive plan to facilitate navigation and prevent destructive floods.

The daunting task of the MRC required its engineers to study, test, adopt, and discard river engineering techniques employed in Europe and elsewhere throughout the world. Congress initially prohibited flood control work since it viewed levee construction as a local responsibility. Until the authorization of federal flood control in 1917, the MRC field work focused on mapping the Mississippi, studying its hydrologic patterns, and making navigation improvements. The latter consisted of closing crevasses in levee lines that caused shoaling in the river, building experimental dikes, and placing great mattresses formed out of willows on the banks to prevent scouring and caving.

These tentative measures did little to deepen channel crossings. Pressed by commercial interests, the MRC began experimenting with dredges, and in 1896 Congress authorized the development and maintenance of a 9-foot channel 250 feet wide from Cairo, Illinois, to Head of Passes. Between 1896 and 1928, dredging and bank revetment became the principal means of sustaining reliable low-water navigation as dikes were dropped from the river engineering inventory. The MRC examined several alternatives, and by the early 1920s adopted articulated concrete mattress as the best means of armoring the banks. First developed in Japan, the technique consisted

of joining together small concrete blocks with wires and cables to form resilient, flexible mats.

The cataclysmic 1927 flood resulted in the 1928 Flood Control Act which put in place the massive, comprehensive Mississippi River and Tributaries (MR&T) Project. Even though the valleywide undertaking focused on flood control, it included channel stabilization provisions. Dikes and other contraction works returned as a river engineering option, and the MRC began stepping up revetment work and the acquisition of larger, more efficient dredges. Generous funding for navigation work continued throughout the 1930s thanks to MR&T appropriations, as well as additional support under the National Industrial Recovery Act and other work-relief programs. The MRC also conducted a cutoff program on the Lower Mississippi that shortened the river's navigation channel by some 150 miles and reduced flood stages. Channel stabilization work went forward during a coeval expansion of river commerce. By 1941, some 120 miles of bank protection had been completed at about 96 locations on the Lower Mississippi, and the MRC dredge fleet consisted of 11 government-owned vessels and several hired under contract. After seven decades, the river stood ready to play its part in national defense.

By December 1941, more than 12,000 miles of navigable waterways existed within the Mississippi River basin. Improvements on the Middle and Lower Mississippi River provided a reliable 9-foot channel from Baton Rouge to St. Louis. Forty-six locks and dams offered the same navigable depth up the Ohio River to Pittsburgh, and similar works extended barge traffic to vital industrial and mining areas on the Allegheny, Monongahela, and Kanawha rivers. The once treacherous and unreliable Upper Mississippi featured a stair-step system of navigation pools created by 26 locks and dams that linked Minneapolis to other major transportation routes. Canalization of the Illinois River connected the Mississippi and the Great Lakes; while further south the Gulf Intracoastal Waterway (GIWW) neared completion, providing 12-foot navigable depths from Corpus Christi, Texas, to Florida's west coast. As war clouds gathered, the Mississippi River navigation system seemed prepared to meet the challenges of mobilization.

Providing a sound navigation system comprised only half of the World War II inland navigation mobilization story. Direct federal investment in the revival of the towing industry proved equally important. The glory days of Mississippi River packet boats lasted until the Civil War, but the river fleet was devastated and only partially rebuilt after the end of hostilities. Waterways traffic fell off due to railroad expansion, and competitors expedited the demise of waterborne transportation by buying up Mississippi River packet lines to destroy the industry. By World War I, common carrier use of the Mississippi navigation system was at a virtual standstill. Steel, oil, and coal companies owned the few towboats and barges that plied the river.

The Defense Plant Corporation towboat Guadalcanal.
(St. Louis Mercantile Library Association)

Wartime demands so congested the railroads that Congress federalized all existing navigation equipment and allotted $3.9 million for the construction of new towboats and barges. In 1920, this federal barge service became the Inland and Coastwise Waterways Service that struggled because year-to-year funding inhibited effective planning. In 1924, Congress accepted proposals to transform the fleet into a publicly owned corporation with the creation of the Inland Waterways Corporation (IWC). The legislation provided for $5 million in stock subscribed entirely by the

federal government. Colonel Thomas Q. Ashburn, a Corps officer, became chairman-president of the IWC and enjoyed a free hand in managing its affairs. The legislation further stipulated that the corporation would be sold once private river traffic revived on the Mississippi River system.

The IWC met the expectations of its founders. From 1924 to 1938 the IWC achieved a total net profit of $2.9 million. Its books were in the black for 11 years of the 15-year period. In fact, 1938 was the most profitable in the corporation's history due to a 32.5 percent increase in tonnage handled throughout the system. Congress gradually extended the scope of IWC operations from the Mississippi and Warrior rivers to all improved tributaries of the Mississippi system. Federal barge traffic on the Illinois River opened in 1931 and by June 1933 operations opened to Chicago.

Throughout its first 15 years, the IWC demonstrated to the private sector the profitability of navigation on the inland waterways. The federal barge fleet complemented and vindicated Corps river improvement projects and attracted private carriers to the rivers. The IWC also made important advances in the field of navigation technology, fought tenaciously to establish joint rates and through routes with railroads, and helped communities build terminal facilities.

One of the IWC's first priorities was developing floating equipment designed for variations in river conditions. During the 1920s and early 1930s, the IWC was virtually the sole source of technological innovation in this field. Building on experimental towboat work conducted largely by the MRC before World War I, the IWC led the way in research and development of towboats, barges, methods of propulsion, and fuel economy. Much of this effort redounded to the benefit of the emerging private waterways industry.

The IWC also promoted the development of river terminals to handle freight. It loaned funds to state and municipal harbor commissions as well as private industries. Once built, the terminals were initially leased to the IWC for operation and maintenance. The corporation paid the owners 15 cents per ton of freight handled until the original investment was amortized—after which the IWC entered into a straight annual contract with the owners. To encourage river communities to build terminals, the IWC offered the services of

engineers who conducted traffic surveys, determined economic feasibility, and prepared preliminary designs. By the mid-1930s, 12 cities had built terminals either with direct aid or encouragement by the IWC.

Ironically, the IWC became the victim of the industry it revived. As private navigation companies developed on the Mississippi system, opposition to the corporation became strong and articulate. The once highly touted savior was deemed a government-owned competitor that stifled private investment in the waterways. Opposition also came from seaboard port interests, railroads, and river communities not served by the IWC.

After 1940, the IWC showed successive annual losses primarily due to shipping huge amounts of freight during World War II. The corporation, which was only reimbursed for direct expenses, was left at war's end with worn, obsolete equipment and no means of acquiring the capital to replace it. Consequently, profitable operations appeared hopeless, and its assets were sold to a private company for $9 million in 1953. The IWC was a unique, innovative undertaking that revitalized navigation on the inland waterways. Working in tandem with Corps navigation improvements, it helped resurrect the navigation industry that proved to be of significant strategic value during World War II.

Clearly the Corps and the towing industry were in a strong posture when the challenges of mobilization presented themselves. Some 1,000 towboats and 5,000 barges plied the inland waterways in 1941, confirming the successful stimulus of the IWC to waterborne transportation. The network of regulated rivers and channels performed admirably. The only additional major construction work involved deepening and widening the GIWW in 1942 to expedite the movement of petroleum.

The civil works program naturally suffered as materials, personnel, and machinery shifted to wartime objectives. The Corps sharply curtailed construction of dikes and levees although some bank revetment work continued. The MRC districts even returned to using willow mats for bank protection due to shortages of concrete, cable, and wire. Corps dredges remained in service keeping shallow crossings open during low water. Many employees joined the military while

the districts shifted their focus from river improvements to building air bases, camps, depots, coastal fortifications, barges, and industrial plants.

The appalling destruction of shipping by German submarines off the Atlantic and Gulf coasts in 1941 and 1942 required shifting much of the coastwise shipping to protected shallow-draft navigation routes. This placed an additional annual burden of some 100 million tons on inland barge lines and operators using the Gulf and Atlantic coastal waterways. The challenge to transportation planners far exceeded the daunting task of developing additional capacity to meet wartime demands. The burden placed on the transportation system included changing the pattern of commodity flow and exchange. Barge lines, railroads, and truckers found themselves moving unfamiliar commodities between unaccustomed origins and destinations. The war upset the normal balance of distance, load, and back haul. Furthermore, reallocations of strategic materials such as steel made it difficult to obtain new equipment, and terminals became badly congested. A complete realignment of rolling and floating equipment was required to coordinate the movement of commodities and determine which of the overtaxed transportation modes should carry specific categories of goods.

Clearly, all transportation mediums—waterways, highways, railways, pipelines, and airlines—needed coordination to ensure efficient movement of commodities, equipment, and military personnel. This effort also required careful consideration of civilian needs and the overall health of the economy. By early 1942, all ocean tankers not sunk by enemy submarines were withdrawn from the Gulf-Atlantic coastwise trade and assigned to convoy duty. This decision presented difficult circumstances. The task of moving vast quantities of petroleum products from Texas and Louisiana oil fields and refineries, normally handled by coastwise shipping, fell to other forms of transportation. Meeting this challenge required major changes in the movement of waterborne traffic and direct federal regulation of the industry. Less than two weeks after Pearl Harbor, President Franklin D. Roosevelt signed an executive order creating the Office of Defense Transportation (ODT) and charging it with coordinating the nation's transportation system. River transportation fell under the

auspices of the Inland Waterways Division of the ODT Waterways Transportation Department. Two other divisions covered Great Lakes and coastal traffic.

In June 1942, ODT issued its General Order Number 19 that sought to increase the flow of petroleum and its products to Atlantic Coast ports by regulating the routes of inland vessels. Under its provisions, all inland craft designed or converted for moving bulk liquid cargo could be operated only when authorized by the ODT. The ODT required permits for tows or vessels moving oil and gasoline in any direction other than generally north and east—the areas of deficit. Cross hauls and back hauls were thus eliminated and the flow of barges speeded up. Subsequent ODT orders regulated the leasing, chartering, and operation of all inland towboats and barges to ensure these important resources met strategic needs and expectations.

For most of the war, ODT focused its efforts on moving petroleum products from west to east to meet domestic and military fuel requirements. Most naval ships and oceangoing transports bunkered on the East Coast and required a reliable supply of fuel. Virtually all tankers carrying refined products to overseas destinations merged into large convoys of other merchant ships transporting military personnel and the implements of war to the European theater.

A shortage of available barges, particularly tanker barges, delayed the towing industry's ability to shoulder its added responsibility. Obtaining new equipment was difficult since shipyards competed with other strategic manufacturers for steel and essential equipment. Nevertheless, an "energy crisis" on the East Coast required the inland waterways to play a major part in mobilization. In the spring of 1942, the government wrestled with an oil shortage on the Atlantic Coast. The daily domestic and export demand exceeded 1.3 million barrels; the daily shortfall stood at 175,000 barrels.

In 1942, the Corps, at the request of the Director of Defense Transportation, transmitted a report to Congress prepared by the Board of Engineers for Rivers and Harbors entitled *Use of Barge Transportation for the Movement of Petroleum*. The study estimated that railroads and pipelines could move only 700,000 barrels per day, requiring tankers

and barges to handle 600,000. With most oceangoing tankers engaged in merchant shipping, it seemed apparent that the inland waterway system should take up the slack.

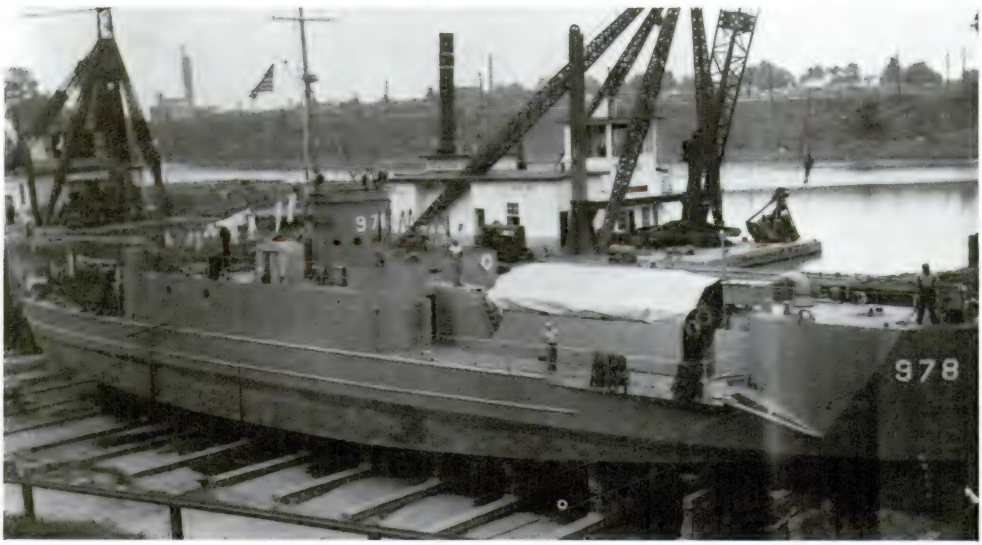
The Corps' report discussed three alternative routes for supplying petroleum to the East, each using a combination of transportation modes. However, they all featured a prominent role for barges. While acknowledging some obvious shortcomings in barge utilization—such as their slowness and the need for new equipment—the report noted many advantages. The first was cost. At that time, the average unit cost of transporting oil by barge was 1.25 mills per ton mile; by pipeline 3.2 mills; and by rail 8.3 mills. The study also noted that shifting more oil to barges could be done quickly since towing units could be assembled piecemeal as equipment became available. Barge transportation offered flexibility so that routes and points of pickup and discharge could be rapidly altered. Finally, barges and towboats could be easily converted from wartime to peacetime use. Consequently, the investment in new equipment to address the immediate crisis on the East Coast would not be lost once the war ended.

Many of the Corps' contentions were corroborated by the findings of the Interstate Commerce Commission and other groups who expanded the analysis to other commodities. *Fortune* magazine examined the cost of shipping 5,000 tons of finished steel from Pittsburgh to New Orleans. The cost, it discovered, was $32,550 by barge compared to $72,000 by rail. The magazine also concluded that building railcars to carry 60,000 barrels of oil would consume five times as much steel as a corresponding barge capacity. In 1942, the largest steel barges could carry 3,000 tons of freight, the equivalent of 75 box cars. A large towboat could push 30 or more barges, the equivalent of 375 freight cars or 7 average trains. During the war, the average tow was 5,000 tons or roughly 126 freight cars.

Without doubt, the movement of crude oil and refined petroleum products constituted the greatest contribution of the inland waterways and towing industry to the nation during World War II. Throughout the war, IWC and privately owned towboats pushed tank barges with a capacity of 5,000 to 18,000 barrels, assembled into 120,000-barrel units capable of moving the equivalent of two full trainloads or one large

oceangoing tanker. On the intracoastal waterways, tugboats handled tows up to 40,000 barrels, while on the Great Lakes, self-propelled barges and lake tankers carried large cargoes of petroleum. From mid-1942 to the close of the war, this vast inland fleet handled more than 1 million barrels per day.

During April 1943, petroleum products moved north and east along the inland routes in the following daily pattern: 52,000 barrels passed New Orleans going east along the GIWW, 62,000 barrels passed Baton Rouge heading north, 98,000 barrels passed Memphis going north, 78,000 barrels passed Cairo heading east on the Ohio River, and 28,000 barrels passed Cincinnati going east on the Ohio River.



Navy ship in dry dock at Lock and Dam 41 on the Ohio River.
(St. Louis Mercantile Library Association)

Meeting the mobilization challenge meant establishing new waterways shipping patterns, expanding old ones, and working out intermodal transfers with railroads and pipelines. Heating oil, gasoline, and aviation fuel began moving up the Mississippi River system in great quantities to points as far north as the Twin Cities and Pittsburgh. Tows of crude oil passed up the Mississippi, Ohio, and Kanawha rivers to inland refineries that converted it to gasoline which reached the East Coast by rail and pipeline. The products of Texas refineries moved eastward along the GIWW to Carabelle, Florida, where a rapidly constructed pipeline carried gasoline

to Jacksonville. From there it moved northward by barge along the Atlantic Intracoastal Waterway.

The linkage of barges and pipelines proceeded apace. In addition to the critical Carabelle connection, pipeline-barge terminals operated at locations such as Helena, Arkansas; Richmond, Virginia; Wood River, Illinois; Mt. Vernon, Indiana; and Steubenville, Ohio, among others. Thus, towboats and barges assumed the responsibility for one lap of the long journey from wells and refineries to points of consumption.

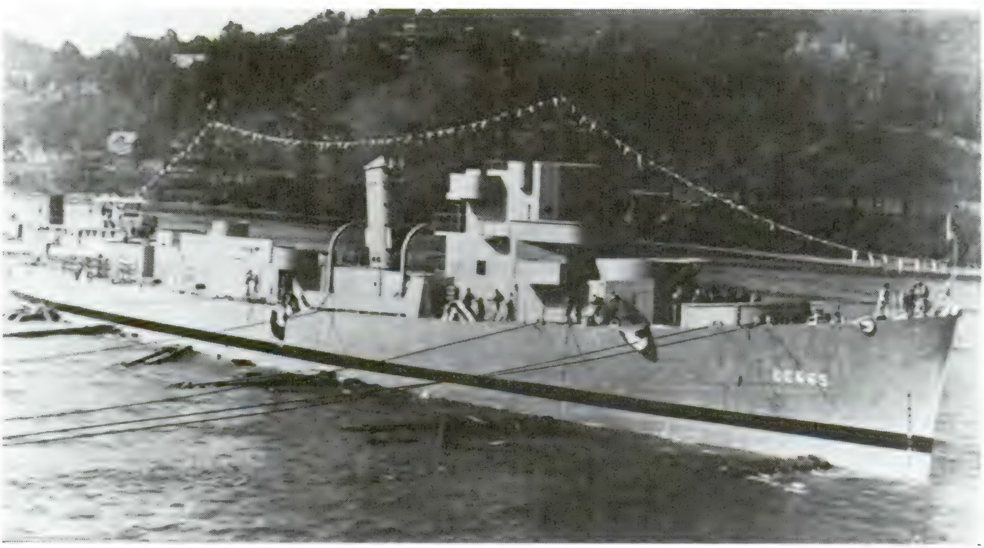
The incessant demand for petroleum products required the conversion and construction of additional floating equipment. The ODT sponsored an extensive power boat and barge building program funded by the Reconstruction Finance Corporation and executed by the Corps' Philadelphia District. This effort added 21 modern 2,000-horsepower towboats and 125 new steel tank barges to the inland fleet. In addition, 116 dry cargo steel barges were taken from the IWC and private carriers and converted to liquid cargo use. The Corps also managed construction of 100 powerful tugboats for operation overseas and on the GIWW, as well as 245 emergency wooden tank barges put into service due to the lack of steel. Collectively, the new and converted barges increased the petroleum carrying capacity of the inland fleet by some 2.2 million barrels.

The former stream of petroleum moved on the inland and coastal waterways grew to a torrent. In 1942—the first full war year—inland waterways carried 406.2 million barrels, which grew to 528 million in 1944. The peak month occurred in October 1944. Tows delivered 50.4 million barrels, an average of 1.7 million barrels a day. During World War II, the inland waterways system accounted for some 1.8 billion barrels, a daily average of some 1.3 million barrels. When one considers that the daily refinery capacity of the United States was 5 million barrels, it is apparent the inland waterways comprised the vital link in the petroleum transportation network.

Even though petroleum comprised the major commodity of inland waterborne traffic, barges also handled other strategic materials such as coal, steel, sulfur, toluene, and other chemicals. The improved waterways of the Mississippi

River system also served as a highway for thousands of Army and Navy vessels built at inland shipyards along the Mississippi and Ohio rivers. This enabled the large coastal shipyards to focus on constructing warships and large merchant vessels.

Inland shipyards built nearly 4,000 craft of various types during World War II. These boats that came down the Mississippi River included submarines, frigates, destroyer escorts, minesweepers, small cargo vessels, and landing craft. New shipyards sprang up throughout the Mississippi and Ohio river valleys, often on land purchased by the federal government. The Cargill Corporation, for example, created a shipyard in former cornfields at Savage, Minnesota, and on the Minnesota River near Minneapolis. The "Meadowland Shipyard" produced small oil and gas tankers for the Navy that remained in service until the 1970s. The *Namakakon*, launched on 28 October 1944, delivered fuel



Destroyer escort built at Pittsburgh, Pennsylvania.
(Mississippi River Commission History Center)

oil to Pearl Harbor and shuttled oil and gas to the central Pacific island naval bases. The *Mattabesset*, launched in November 1944, also made fuel runs to Pacific islands before being transferred to the Atlantic Fleet. Inland shipbuilding firms pridefully noted that many of these vessels were built by former tradesmen and farmers with no prior experience in marine engineering and construction.

Some 40 river pilots joined the Coast Guard and assumed the responsibility of ferrying vessels built at inland shipyards down the tributaries and main stem of the Mississippi to the Gulf. In many instances, innovations enabled larger craft such as submarines to safely pass through the inland navigation system. For example, 28 submarines built at Manitowoc, Wisconsin, on Lake Michigan, entered the Illinois waterway at Chicago before being placed in special floating dry docks at Lockport, Illinois. The largest IWC towboats, especially the *Minnesota*, moved the submarines under strict security. They went southward only at night, and military as well as local law enforcement authorities stopped traffic on all bridges as they passed beneath them.

Landing craft comprised the largest category of inland shipyard production. Landing ships, tank (LSTs) and similar vessels built far from the Atlantic and Gulf coasts collectively could accommodate the movement of more than a million tons of cargo or 175,000 invading troops. One LST, the 512, participated in war bond sales and other public affairs activities before going to war. It visited a host of river towns with its deck converted into a Pacific island scene featuring a Japanese Zero, two artillery pieces, and a Sherman tank. The display also included a miniature beachhead operation painted by combat artists. When the LST arrived at St. Louis, the bow ramp opened and an "alligator" amphibious landing vehicle and a tank splashed into the water and went ashore.

The waterways industry underwent a painful transition during the war despite the upsurge of petroleum movement. River commerce experienced a renaissance in the 1930s thanks to navigation improvements and the stimulus of the IWC. Total annual tonnage on the Mississippi system increased by 70 percent between 1939 and 1941—from 58.4 million to 99.6 million tons. Nevertheless, from 1942 to the end of the war, tonnages generally stagnated and fell to a low of 95.5 million in 1945. Clearly, in one sense the war disrupted a healthy towing industry growth that did not recover until 1947 (118 million tons). Yet, the opening of new markets, traffic patterns, and intermodel linkages laid the foundation for huge postwar expansion that climbed to 138.1 million tons in 1950.

Total Tonnage of Traffic on Mississippi River Navigation System, 1939-1950	
1939	58,420,985
1940	88,980,317
1941	99,595,957
1942	100,351,044
1943	93,561,533
1944	101,340,788
1945	95,543,335
1946	95,648,203
1947	117,973,935
1948	125,437,742
1949	122,313,602
1950	138,144,871

Total tonnage of traffic on Mississippi River navigation system, 1939–1950. (Commercial Statistics, 1940–1951, *Volume 2,* Annual Reports, Chief of Engineers)

In the first year after Pearl Harbor, the navigation system experienced a painful transition. By 1941, a balanced pattern of river traffic had developed with roughly 55 percent moving upstream and 45 percent downstream on the Mississippi River and its navigable tributaries. Coal moved downstream to mills throughout the Ohio Valley; grain arrived at Baton Rouge and New Orleans for the export and coastwise trade; barges delivered steel to locations throughout the inland and coastal system; and many types of manufactured items moved south for foreign and coastal markets.

The war radically altered this comfortable and prosperous pattern. Hostilities shut off export movements of grain and many other commodities. The government requisitioned all coastwise boats, further limiting the southbound movement of goods. The transport of steel shifted almost entirely to rails since it was urgently needed at coastal shipyards. The towing industry gradually recovered steel contracts, but the annual volume never attained prewar levels. Bulk shipments destined for the West Coast through the Panama Canal shut down before the war began. Finally, government restrictions on warehousing nonstrategic items further retarded the flow of

commodities such as sugar to the Gulf. Some new southbound movements sprang up of commodities such as soybeans, benzol, and naval craft; but, for the most part, the once balanced pattern changed to 85 percent northbound and 15 percent southbound. The mix of northbound commerce also altered considerably. Prior to the war, petroleum products, sulfur, sugar, and imports such as coffee, cocoa, and rubber moved northward via barge. After December 1941, imports were choked off and sugar was tightly rationed. However, increased demand for petroleum, sulfur, and scrap metal more than compensated for these losses.

Expanded commerce prompted Lower Mississippi interests to advocate a deeper channel between Cairo and Baton Rouge. As a result, the 1944 Flood Control Act authorized a 12-foot channel for this reach of the river. A channel improvement program consisting of revetments, dikes, and dredging would achieve the channel improvement. Bottlenecks on the GIWW induced Congress to approve a dredged canal from the Rigolets (an outlet of Lake Pontchartrain) to the inner harbor at New Orleans. This expedient measure sparked interest in a deep-water ship canal project that resulted in the subsequent authorization (1956) and completion of the Mississippi River-Gulf Outlet in 1965. Further north, the disruption of strategic transportation prompted the Corps and Congress to address the treacherous chain of rocks that jutted from the Mississippi's west bank between the mouth of the Missouri River and St. Louis. In 1945, Congress authorized a bypass canal and locks system (No. 27) that eliminated this major hazard.

The contributions of the inland waterways during World War II lubricated congressional approval for navigation and harbor projects at Minneapolis, Memphis, Baton Rouge, and other inland cities. The influx of federal dollars spurred municipal and private sector investment in terminal facilities which stimulated river commerce following the war. Petitioners besieged Congress for assistance in creating and upgrading harbors. The anticipation of a 12-foot channel from Cairo to Baton Rouge and improvement of the ship channel through the passes encouraged commercial interests to expeditiously develop port facilities.

At Memphis, the existing topography limited port expansion. The crowded shore facilities strained under a wartime burden of nearly 4 million tons per year. The existing 36 port terminals failed to accommodate the anticipated growth in river traffic, and expansion seemed improbable due to the geologically constrained site. In October 1945, Brigadier General Max Tyler, president of the Mississippi River Commission, presented a plan to Memphis city fathers that served as the precursor for ports elsewhere on the river. The "Tyler Plan" proposed blocking off a chute that carried a portion of the Mississippi's flow around President's Island just south of Memphis. The remainder of the chute would be dredged out as a slackwater harbor for Memphis. The enlarged chute would open a huge expanse of land for the development of port facilities by city and private interests. The project was authorized in 1946 and work began in 1948, but due to funding cutbacks, it was built in stages and not completed until 1967. By that time, the harbor was already handling nearly 8 million tons of cargo annually.

The Devil's Swamp Harbor near Baton Rouge also sprang from the World War II experience. Because the city stood at the upper end of a corridor of heavy industry that flanked the river south to New Orleans, developers correctly assumed that Baton Rouge should be a major deep-water port with facilities to match. Devil's Swamp, just north of the city and a former chute of the Mississippi, offered a logical port site. The harbor, authorized in 1948, called for 5 miles of dredged channel in increments of 2.5 miles each. Construction of the first portion began in January 1958 and finished in July of the following year. Within ten years, annual harbor tonnage grew from 41 to 77 million tons.

The waterways of the Mississippi River navigation system provided a vital transportation link during World War II. Thanks to the Corps and the IWC, the nation reaped the benefits of a revived towing industry and a safe, reliable waterway system. World War II also stimulated the latent growth of waterborne commerce, which did not manifest itself until after the war. During the conflict, tonnages carried by barges fell slightly even though certain bulk commodities could be transported more efficiently by river than rail.

Ultimately, the vast network made two major contributions to victory: providing a thoroughfare for military vessels built at inland shipyards and facilitating the flow of petroleum products to the oil-short East Coast. In every other respect, the waterways played an essentially backup and supplementary role.

Yet, the war years served as a transition period beginning with the renaissance of the inland navigation industry and closing with the dawn of a new golden era of unprecedented growth. The cost-effectiveness of waterborne transportation, the abundance of new equipment built at federal expense and sold after the war, the continuing efforts of the MRC and other Corps entities to make the rivers more navigable, and the general boom of the postwar period reaffirmed that waterways are a cornerstone of economic prosperity and national defense.

Sources for Further Reading

An overview of wartime transportation challenges may be found in Chester Wardlow, *United States Army in World War II. The Technical Services. The Transportation Corps: Movements, Training, and Supplies* (Washington, DC: GPO, 1956).

For specific information on the Mississippi River and other waterways see T. Michael Ruddy, *Mobilizing for War: St. Louis and the Middle Mississippi During World War II* (St. Louis: St. Louis District, U.S. Army Corps of Engineers, 1983) and Edward Hungerford, *Transport for War*, 1942–1943 (New York: E.P. Dutton and Co., 1943).

Rivers in Miniature: The Mississippi Basin Model

by Michael C. Robinson

The decision to build the Mississippi Basin Model (MBM) was a noteworthy undertaking of the Corps of Engineers during World War II. The hydraulic model was a remarkable technological feat in terms of size, innovative design, construction, and resultant contributions to the field of small-scale hydraulics research. Conceived in the late 1930s and built from 1943 to 1966, it replicated most of the Mississippi River and its major tributaries on some 200 acres of funnel-shaped land near Clinton, Mississippi. It offered the appearance of a gigantic relief map with the major streams and topographical features of 41 percent of the continental United States carefully reduced to scale. The facility may be viewed as the Brooklyn Bridge or Hoover Dam of the hydraulics research field—a preeminent structure of unprecedented scale and complexity that represented a rapid advancement of technological frontiers.

The model, designed and built by the Corps' Waterways Experiment Station (WES), also represented a confirmation of the fundamental importance of small-scale hydraulics research within the agency's civil works program. This attainment seems remarkable when one considers that, as late as 1930, many Corps officers and civilian engineers regarded models "as mere toys for youngsters of the profession." Most of the Corps was openly skeptical of the value of models and actually feared they posed a threat to traditional engineering practices based on field data and experience. Until the founding of WES (1929), rivers and harbors work was largely an empirical process and little attention was given to conducting model experiments using the fundamental principles of hydraulic similitude.

The traditional Corps' outlook was apparent during the 1920s as John R. Freeman and other civil engineers campaigned for the creation of a national hydraulics laboratory

contained a paragraph enabling the Chief to create a hydraulics laboratory for studying details in conjunction with the flood control plan for the Lower Mississippi Valley.

It seems likely that concerns about challenges to the Corps' preeminence in the water resources field were a major factor in the founding of WES. Major General Lytle Brown, Jadwin's successor, noted that engineer officers opposed the Freeman proposal because they feared other agencies might "dictate to the Corps of Engineers as to how the works entrusted to its care should be executed." Brown, like Jadwin, viewed the laboratory's potential benefits as largely tangential—"specific in character. . . not for general informative purposes."

The task of founding WES fell to First Lieutenant Herbert D. Vogel, who had recently completed a Ph.D. in hydraulics in Germany. The constraints he faced were formidable. He was ordered to create a scientific research facility in the face of lukewarm top-level command interest, intra-Corps apathy and hostility, funding and personnel constraints imposed by the Depression, and even the chagrin of now President Hoover upset by the Corps' opposition to Freeman's Bureau of Standards proposal. His only assets were the impetus of the MR&T project and the support of the Mississippi River Commission staff.

The young officer, in addition to his considerable hydraulics expertise, possessed extraordinary personal magnetism, organizational abilities, communications skills, and bureaucratic cunning. During his tenure as WES Director from October 1929 to August 1934, he founded the facility in Vicksburg, Mississippi; oversaw the construction and operation of credible hydraulic models; established the institution's reputation as a major research center through professional publications; and assembled a highly talented young staff that was, according to Vogel, "iconoclastic, brash, and beholden to no one." Through publications in technical journals as well as visits to universities and Corps field offices, Vogel was able to recruit staff and spread the gospel of small-scale hydraulics research. Thus, WES rapidly evolved from a small organization initially employing crude methods into a research institution of acknowledged scientific attainments.

WES researchers advanced both theoretical and applied hydraulics research due to opportunities provided by the MR&T project and other Corps endeavors. The scope of the institution's work was enlarged by the profusion of civil works projects during the New Deal. Former opponents became ardent enthusiasts; a great number of Corps engineers began to make increasingly difficult research demands on WES, forcing the institution to broaden the scope of its activities and refine the accuracy of techniques. By 1937, WES was conducting hydraulics-related studies for every Corps division but one on a wide range of topics relating to the hydraulic features of dams, river canalization, open river regulation for navigation, flood control, coastal harbors and beaches, and miscellaneous subjects.

The most spectacular project undertaken by this rapidly expanding institution was the design and construction of the largest hydraulics model in the world. The MBM became the Corps of Engineers' principal tool for studying flood control reservoir operations within the Mississippi River basin and for fixing and regulating the Lower Mississippi River channel itself.

The Mississippi basin, which covers some 1.25 million square miles, is about 20 times larger than New England. It extends from the Rocky Mountains to the Appalachians, from just above the Canadian border to the Gulf of Mexico. The watershed contains all or part of 31 states and two Canadian provinces and occupies 41 percent of the continental United States. It is exceeded in size only by the Amazon and Congo watersheds. This vast area is divided into six major subbasins: the Upper Mississippi, the Missouri, the Ohio, the Arkansas–White, the Red–Ouachita, and the Lower Mississippi. The first three contain about 900,000 square miles or nearly 75 percent of the entire drainage basin.

In considering this huge basin as a whole with its 15,000 miles of rivers, its thousands of miles of levees, and its some 200 reservoirs (built, authorized, or proposed), it was apparent that many complex problems faced the Corps of Engineers in the development of flood control measures. Of special concern was the task of operating such a large number of reservoirs to ensure proper coordination of floodwater releases.

Major Eugene Reybold conceived the idea for a comprehensive model of the Mississippi River and its tributaries while serving as district engineer at Memphis, Tennessee, during the 1937 flood on the Mississippi River. He formulated the idea that a huge model could be used to develop plans for the coordination of flood control problems, chiefly reservoir operations, throughout the Mississippi basin. When Reybold became Chief of Engineers in 1941, he was able to put his plan into effect. On 23 May 1942, the Chief met with several WES officials in Washington, DC, to discuss the model. Reybold stated that the model would have a great potential value for demonstrating flood control measures to government officials, laymen, and engineers. He also believed that the model could be used to convince Congress of the necessity for centralized control of reservoirs during flood emergencies in the Mississippi River basin. The Chief also viewed this effort as consistent with plans to implement a large civil works program following the war as an adjunct to demobilization. He ordered WES to conduct a preliminary study, which it transmitted to the Chief on 19 October 1942.

The report suggested that the model would have three principal purposes: to determine methods of coordinating the operation of reservoirs to accomplish the maximum flood protection under various combinations of flood flow; to determine undesirable conditions that might result from noncoordinated use of any part of the reservoir system, particularly the untimely release of impounded water; and to determine what general flood control works were necessary (levees, reservoirs, floodways) and what improvements might be desirable at existing flood control works.

General Reybold was sensitive to the fact that personnel, materials, and equipment were in short supply due to World War II and that civilian labor would not be available to start construction of the model. Thus, he developed the idea of using prisoner of war (POW) labor to prepare the model site, since much excavation would be required to mold the terrain in accordance with the general topography of the Mississippi River basin. He immediately began negotiations through the Provost Marshal General for 3,000 German POWs recently captured in North Africa. He also obtained authority to construct an internment camp, called Camp Clinton, at the model site.

Entrance to the Clinton internment camp. (Harold Fonger)

This strategy had an advantage. The model could be started without waiting for approval of the Bureau of the Budget (BOB) and the War Production Board. The Army granted slightly more than one-third of this request. By August 1943, the Corps was paying over 1,000 POWs from Field Marshal Rommel's elite Africa Corps 80 cents each per day to reshape a 200-acre tract to resemble a relief map of the United States. The employment of POWs was not unusual. Captured German and Italian soldiers were used primarily as contract laborers for farmers, businessmen, and local governments and supported the local economies of predominantly agricultural states. Because of the wartime shortage of normal laborers, their work was essential to labor-intensive agriculture. POWs were even used on flood control projects. Besides building the Mississippi River flood control model, in 1945 German POWs reinforced weakened levees along the Arkansas River during severe flooding in western Arkansas and eastern Oklahoma.

Earlier in 1944, the Office of the Chief of Engineers (OCE) tried to obtain $3 million in appropriations for the MBM project. Because it had not made this request in previously submitted supplemental estimates, the BOB demanded an explanation, called for justification of the funds used for POW labor, and directed the Secretary of War to show how the model met the President's definition for projects that could

be started during the war. Essentially this was part of BOB's continuing effort to end the War Department's practice of using military appropriations to finance rivers and harbors and flood control projects the Corps considered essential to the war effort. BOB's principal budget examiner, Charles D. Curran, a former member of the Corps, believed "control of river and harbor work breaks down when. . . performed with so many appropriations."

Secretary of War Henry Stimson tried to convince BOB that neither his department nor the Corps was seeking to manipulate the appropriations process. He explained that the MBM was a central element in the construction and operation of authorized flood control projects in the Mississippi basin. Rather than turning to supplemental funds, the Corps had relied on POW labor. He believed this was appropriate since the project was designed to provide "substantial benefits of a civilian nature for a large portion of the country." If the war should end sooner than expected, the project would generate well-designed plans and a more effective postwar public works program. This argument was effective. BOB approved completion of the model in an attempt to reduce postwar problems. Congressional authorization soon followed.

During World War II, more than 400,000 captured Axis soldiers were transported to the United States for internment at locations throughout the country. Of this total, some 20,000 were sent to Mississippi. Four large base camps were created in the state: Camp Como in the northern delta, Camp McCain near Grenada, Camp Clinton near Jackson, and Camp Shelby in the southern part of Mississippi. During 1944 and 1945, smaller branch camps were built at Greenville, Greenwood, Belzoni, Leland, Brookhaven, Indianola, Clarksdale, Drew, and Picayune.

The site of the Clinton camp was purchased in 1942 at a cost of $49,000. It consisted of 790 acres and would eventually house 3,000 POWs. The compound was enclosed by a 10-foot-high woven wire fence topped with barbed wire. Guard towers equipped with search lights and telephones were placed every 200 feet. Ten feet inside the outer fence was an inner fence of similar height and construction. A deadline was established 20 feet inside the inner fence and marked by evenly spaced white stakes.

The first prisoners began arriving in mid-August 1943. Most had been captured in North Africa and soon adapted to the damp, torrid Mississippi summer. Despite working eight hours per day on the model, the prisoners had a relatively comfortable existence. The food was good and plentiful, and most of the POWs actually gained weight during their confinement. Employees of WES often timed their visits to the model site so they could have lunch or dinner at the camp's mess. In contrast to supply shortages and rationing within the American civilian community, the interned Axis soldiers enjoyed a wide variety of choice foods including the best grades of beef and butter. The camp also featured a canteen where prisoners could buy tobacco, soft drinks, books, periodicals, toiletries, beer, and many articles no longer available to civilians. One POW later recalled that after overindulging in beer, it was hard to spend the morning toiling in the hot sun while fighting a hangover.

German prisoners of war clear the site for the Mississippi Basin Model. (Harold Fonger)

The prisoners devoted their spare time to an array of games and sports including heated competition on a regulation soccer field. They also had access to baseball, basketball, volleyball, and horseshoes. Those inclined toward less strenuous pursuits could use the camp's 6,500-volume library or participate in a theatrical group, a jazz band, and a symphony orchestra.

The day's activities included reveille at 0530, followed by breakfast and a working day that ran from 0800 to 1600 hours. In accordance with the provisions of the 1929 Geneva Prisoner-of-War Convention, the work could be neither unhealthy nor dangerous and could not involve the production of military equipment. Officers and noncommissioned officers (NCOs) were not required to work but could volunteer to do so. Prisoners were paid 80 cents a day and officers and NCOs were paid whether they worked or not. A German lieutenant received $20 per month, a captain $30, and officers of higher rank got $40 per month. The prisoners received canteen scrip in lieu of cash.

The Geneva Convention required that officers receive special treatment. Camp Clinton featured a special officers' compound situated apart from the enlisted men's barracks. During the war, 31 Wehrmacht generals were confined at the camp, including Juergen von Arnin, commander of Army Group Africa, and Dietrich von Cholitz, former commander of Paris, who refused to burn the city when ordered to do so by Hitler. Each of the general's quarters was comfortable, well-furnished, and contained a refrigerator.

Between August and May 1946, when the last POWs returned to Germany, the German soldiers completed much of the preparatory work required for construction of the model. They cleared nearly 600 acres of land, built roads and bridges, and dug drainage ditches as well as storm sewers. Using mainly picks, shovels, and wheelbarrows, the Germans moved more than 1 million cubic yards of earth. The total value of this labor to the project is estimated at $6 million.

Despite a relatively comfortable lifestyle, the POWs attempted numerous escapes. The most spectacular was a 3-foot-wide tunnel dug from a barracks approximately 100 feet from the compound fence. The prisoners made ingenious, small, round cloth packs with drawstring openings to conceal the dirt being taken from the tunnel. They concealed the sacks inside the legs of their trousers. At the model site they loosened the string and scattered the dirt as they labored. The tunnel, which included electric lights, was discovered as it reached within 10 feet of the fence. The burrowers were then sent to a more secure camp in Enid, Oklahoma.

Aerial view of the Mississippi Basin Model during excavation.
(Waterways Experiment Station)

The feasibility of such a model as the MBM had been demonstrated by the Mississippi River Flood Control Model, operating at WES for about a decade. This earlier model, built to a scale of 1:2,000 horizontally and 1:100 vertically, created in miniature a 600-mile stretch of the Lower Mississippi River from Helena, Arkansas, to Donaldsonville, Louisiana. It proved invaluable by accurately reproducing observed floods and enabling researchers to portray the effects of flood discharges greater than heretofore experienced. It helped to establish levee grades, to check the effect and result of cutoffs in the main channel, to determine the character of storage in backwater areas, and to illustrate the operation of floodways.

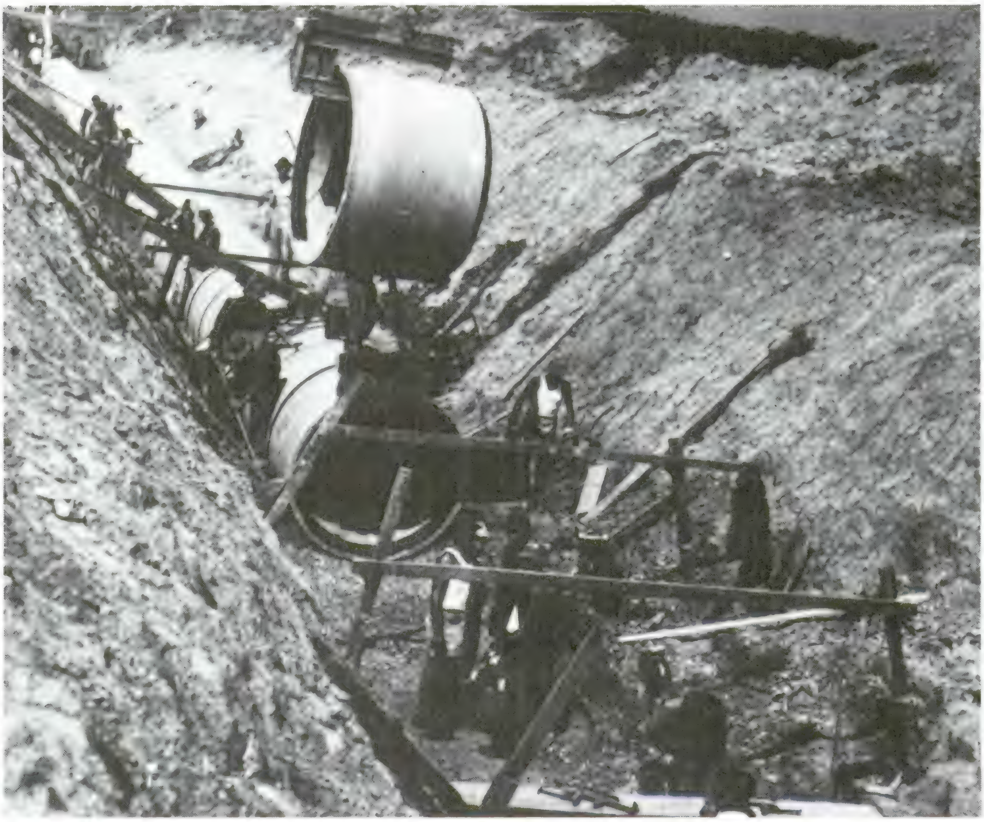
The MBM was designed to the same scale as the model at Vicksburg. Thus, the drainage basin of 1.25 million square miles required that the model cover an area of approximately 200 acres. The network of streams 15,000 miles in length was nearly 8 miles long in the model. The model reproduced all existing and proposed flood control reservoirs, as well as levees, dikes, floodwalls, floodways, and other pertinent works. The size of the model streams may be illustrated by considering the Lower Mississippi River, which in some places is 1 mile wide and varies from 50 to 150 feet in depth depending upon the stage. In the model, this portion of the river

would have a width of about 30 inches, exclusive of the overbank areas, and a depth of from 6 to 18 inches. Most of the Mississippi and large portions of major tributaries (as well as overflow areas) were to be molded in concrete while the intervening topography was covered with sod. WES designed the model to operate either as a whole or in part. Accordingly, portions of the main stem of rivers such as the Tennessee, Arkansas, and Missouri could be tested independently to study local flood control problems. Thus, the MBM was designed, in a sense, as many models in one.

To be whimsical, if one were a Lilliputian resident in this model conforming to its laws, he or she would be about ¾-inch tall, and because of the distorted scale, as thin as tissue paper. The normal 8 hours sleep would last but 2.4 minutes, while lunch hour would be only 18 seconds. The maximum discharge occurring in the model was about 2 cubic feet per second or about 1,000 gallons per minute.

Since the model location would be transformed into a giant relief map of the drainage basin with a maximum difference in elevation of 50 feet, the site selection process involved finding a location that would require the least possible amount of grading. The Clinton site was selected because it offered as close a resemblance to the finished topography as could be found near Vicksburg. Nevertheless, approximately 1 million cubic yards of excavation was needed to produce the required miniature basin. The grading of the site was unusual in that a topography consisting of ridges and valleys was artificially formed rather than a normal grading operation in which a more or less level surface is desired.

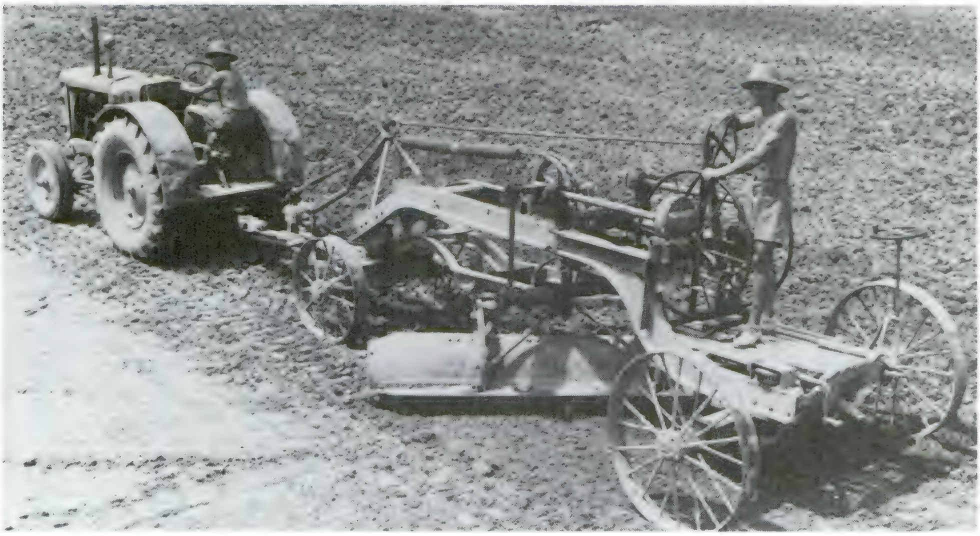
To simplify the field work of laying out the model, a rectangular grid of 100-foot squares was superimposed on the Bonne projection used for the site. In preparing the original grading plans, cuts and fills were projected for a haul of less than 500 feet in as many areas as possible. Limiting hauls to 500 feet was necessary because of the wheelbarrow-and-shovel nature of initial excavation operations. Fortunately, this labor-intensive effort did not last many months because WES obtained large earthmoving equipment which facilitated completion of the rough grading.



German prisoners of war place drainage system. (Waterways Experiment Station)

In grading the site, great care had to be taken in compacting the fill. Obviously any settlement would be disastrous to the model. The fills were made in accordance with standard procedures established by the WES Soils Division: placing the earth in 8-inch lifts, obtaining the proper moisture content, and then compacting with sheepsfoot rollers to obtain the desired density. Placing the fill in layers simplified the formation of the topography. WES prepared contour maps to show the extent of each lift, or of several lifts, in order to obtain the proper shape of a ridge or a valley.

Since the model streams themselves could not discharge rainfall occurring over the model area, a storm-water drainage system had to be provided; the annual rainfall at Clinton is approximately 55 inches. A separate water supply system provided the actual discharge of the model streams so that flows in the model could be regulated. To provide for surface

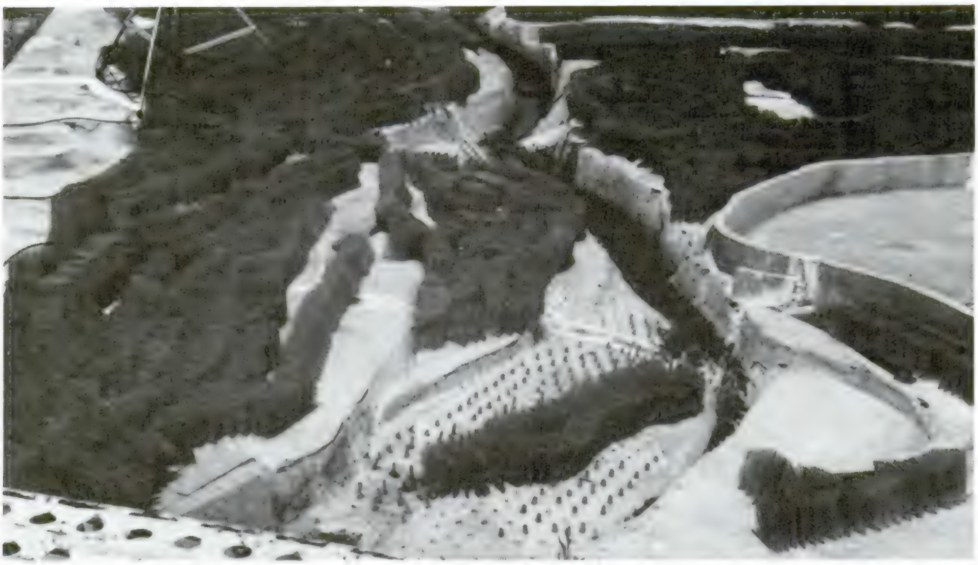


Grading the Mississippi Basin Model site. *(Waterways Experiment Station)*

drainage, each miniriver valley was furnished with inlets to intercept water running in small V-shaped ditches on each side of the model streams. This water, in turn, was carried underground through laterals to outfall sewers discharging into a drainage canal surrounding the model. The length of pipe required amounted to some 85,000 feet, varying in size from 8 to 60 inches.

Corps division and district offices and other government agencies furnished the bulk of the physical data required for the design, construction, verification, and operation of the model. During the design and construction process, a large force was engaged in compiling, cataloging, and analyzing the following types of physical data: levee grades and alignments; location of railroads, highways, bridges, and similar construction; flood photographs; and steamflow data such as stage and discharge measurements, rating curves, and water–surface profiles.

Construction of the concrete portion of the model began in 1946 and continued at a varying pace due to inconsistent funding until its completion in 1966. This huge portion covered so large an area that it was built in sections with expansion joints between the sections to absorb the expansion and contraction of the concrete. Individual blocks were outlined on contour maps with a view toward keeping the



Detail of completed concrete portion of the Mississippi Basin Model.
(Waterways Experiment Station)

blocks about 150 square feet in size and rectangular in shape with the ends perpendicular to the channel alignment. At first, WES constructed the model in place on a carefully prepared subgrade using sheet-metal templates cut to the cross sections obtained from topographic maps. However, because an expansive clay beneath the model caused excessive heaving, WES developed a new approach (the coutour method) in 1953. Sections of the model were molded on an assembly line, transported to the model site, and placed on concrete piles. This innovation effectively stabilized the horizontal plane of the model.

Channel roughness elements consisting of brushed and scored concrete, concrete ridges, and concrete as well as brass blocks were installed to size and spacing determined from computations and pilot model studies. Folded screen wire cut to the scale of the average height of trees was placed in the model in accordance with information drawn from aerial photographs. Although construction of the model continued until 1966, individual sections were in operation by 1949. As a section of the model was completed, the roughness added, and instruments installed, it was verified (made to reproduce historical occurrences in nature) and operated for local testing.

The verification process involved the use of historical data to refine the model. A recent flood of considerable magnitude was selected to verify each reach of the model. The model equivalents of the flood flows, from the low stages to the crest, were introduced at the model inflow points and the channel and overbank roughnesses were increased or decreased until the model stages replicated the historical data. Once verified, the model could be used to help forecast probable future occurrences.

Automatic instrumentation was a major, innovative feature of the model. The designers realized that a staff of 600 personnel would be required to manually operate the model. Therefore, the engineers in charge decided to explore the feasibility of using automatic controls. Nearly four years, 1943 to 1947, were devoted to studying and developing these instruments. WES contacted more than 125 commercial firms and conducted many tests. These tests disclosed that the available instruments could not meet the model's rigorous accuracy requirements. After the war, WES prepared specifications, invited bids, and obtained this highly specialized equipment.

Close cooperation among the interested Corps offices was essential to the proper construction and operation of the far-reaching model. Consequently, in 1945 the Corps created a Mississippi Basin Model Board to determine policies and programs for the model's operation and testing. The committee consisted of commanders of the Corps divisions within the basin, the WES director, and a representative of the Office of the Chief of Engineers. This policy-making body was supported by various staff-level committees that helped develop plans, programs, and procedures.

In April 1952, the model dramatically demonstrated its value in a field for which it was not originally planned—forecasting the progression of a flood. WES was asked if the Missouri River section of the model could be operated in connection with a major flood. That portion of the model had been completed and verified and was ready for use. During 15 crucial days, constant communication was maintained between the Missouri River Division, the Omaha and Kansas City districts, and the Waterways Experiment Station. The data furnished by the model were water–surface

profiles, crest discharges, stage and discharge hydrographs, and the identification of critical locations where levee raises were necessary. The information furnished by the model tests was of incalculable value in aiding evacuations and supporting flood-fighting activities.

In April 1973, WES used the model to assist in a flood fight on the Lower Mississippi River. In the fall of 1972, the Mississippi River basin experienced heavy rainfall. The flood control reservoirs along the tributary streams began to fill and the ground became saturated. In the spring of 1973, a serious flood developed. On 12 April, problems developed at the Old River control structure as a wing wall failed and a scour hole developed in front of the structure. The model was put into operation to help determine the effect of opening Morganza floodway on the flow conditions at Old River and on stages in the Atchafalaya basin. The model operated 24 hours a day for the remainder of the flood to help determine which levees were in danger of being overtopped, what portions needed to be raised to contain the flood, and how the operation of Morganza floodway would affect flood stages.

The Mississippi Basin Model, employed on an intermittent basis since the major series of tests concluded in 1971, exceeded the expectations of its inventors. The report-filled shelves of the WES Research Library attest to its role in improving flood control and related practices on the Mississippi and a host of other rivers. It also (in conjunction with many other WES endeavors) confirmed the place of small-scale hydraulics research within the Corps' civil works program. Conceived during World War II, built partially with POW labor, and used for a host of activities, the Mississippi Basin Model has been a good and reliable soldier.

Sources for Further Reading

For an excellent overview of the founding of the Waterways Experiment Station, see Herbert Vogel, "Origin of the Waterways Experiment Station," *Military Engineer* (March–April, 1962): 135–36.

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Special thanks is offered to Terry Winschel, historian, Vicksburg National Military Park, for sharing his unpublished essay on the Clinton prisoners of war camp.

Bonneville Dam's Contribution to the War Effort

by William F. Willingham

When the United States declared war on Japan on 8 December 1941, the need for massive amounts of electrical power to fuel the domestic war effort became immediately evident. Bonneville Dam, which began generating power in May 1938, contributed mightily to this need. Electric power from Bonneville Dam's power plant was delivered by the Bonneville Power Administration (BPA) to public and private customers throughout the Pacific Northwest. During World War II, BPA supplied power to shipyards at Portland, Oregon, and on the Puget Sound in Washington, to aluminum plants scattered throughout the region, and to airplane factories near Seattle.

When work began on Bonneville Dam in September 1933, no one foresaw the need for the huge amount of power the war effort would require. At the time of construction, some even doubted the energy generated by the initial two Bonneville power units (87,000 kilowatts) would ever be fully utilized. Commentary published in the regional and national press expressed the belief that for the forseeable future little market existed for the federal power from Bonneville. As the dam neared completion, the eastern press assailed it as the "Dam of Doubt."

In the midst of the controversy over whether hydropower dams on the Columbia River were needed, another point of contention arose over who would market the electricity produced. To resolve the marketing issue, Congress, in 1937, created BPA to sell and distribute the power generated by the Corps of Engineers at Bonneville Dam. Although originally conceived as an interim measure until Congress could legislate a Columbia Valley Authority patterned after the Tennessee Valley Authority, BPA has continued to function as originally established.

BPA's authorizing legislation required it to sell power in accordance with the policy of "widest possible use of available

electric energy," giving preference to publicly and cooperatively owned distribution systems. The BPA administrator was empowered to construct and operate necessary transmission and substation facilities and to enter 20-year power contracts. Under J. D. Ross, the first BPA administrator, the agency rapidly set out to create a market for Bonneville power and to build the necessary transmission lines. The agency adopted a policy of a blanket or so-called "postage stamp" rate over the entire region served by its transmission system. This approach was designed to encourage the widest possible regional economic development. The initial uniform wholesale rate set by Ross recovered the costs of production and distribution while being cheap enough to stimulate demand.

Aerial view of the Bonneville Dam, 1940, looking downstream.

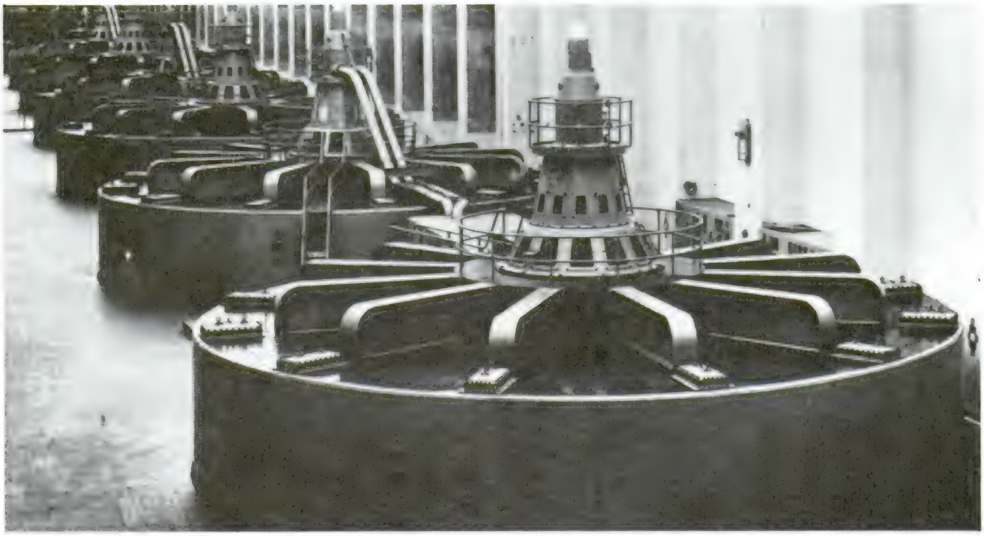
Under Ross's initial leadership, and over the opposition of private utilities, BPA built a high voltage grid for the region. Beginning in July 1938, the engineers at BPA swiftly overcame difficult problems of design, survey, and construction and soon had a network of high tension transmission lines radiating from Bonneville Dam. Next, BPA moved to integrate Bonneville power with that produced by other public and private power systems in the Northwest, allowing the agency to carry out regional planning and become the chief supplier of electric power. By 1941, the major components of the BPA power grid were in place. While BPA developed its

transmission facilities, the Corps of Engineers began adding power-generating units to the Bonneville powerhouse to supply a rapidly expanding market.

Initial authorization of Bonneville Dam provided for a powerhouse with two complete power units and a substructure for the future addition of four units. When Congress authorized the completion of the Bonneville project in 1937, engineers immediately began plans and design for the work necessary to install eight additional units. This expansion required considerable difficult excavation to extend the powerhouse to accommodate the four additional units over the initially authorized six.

Construction on Units 3 through 6 began in the fall of 1938, as the market for low cost electric power expanded beyond all forecasts. Since the first two turbines produced power well in excess of the guarantees, engineers increased the unit size to 54,000 kilowatts. Units 3 and 4 came on line in December 1940 and January 1941, respectively. With war clouds on the horizon, the Corps of Engineers started construction in the fall of 1939 of Units 7 through 10. Expansion of the powerhouse foundation and superstructure for the final units delayed work on Units 5 and 6. Unit 5 went into operation in September 1941 and Unit 6 began service in May 1942.

Excavation for Units 7–10 proved tricky. The powerhouse lay between the Oregon shore and Bradford Island in the middle of the Columbia River, and the engineers found the necessary cofferdams difficult to construct and maintain. Considerable overburden and an earthfill dike connecting the powerhouse with the island had to be removed. In addition, earth and rockfill cofferdams had to be placed up and down stream of the powerhouse. The need to sustain full power production while expanding the powerhouse meant that the lake could not be drawn down, complicating construction of the cofferdams. Once in place, they proved difficult to maintain. At one point, work ceased for several days when a wartime shortage of parts caused water pumps to fail and allowed the site to flood. The Corps placed the final four units on line at three-month intervals in March, June, September, and December of 1943.



Interior of the original powerhouse, Bonneville Dam, shows newly installed generator units.

The speed with which the Corps of Engineers installed generators at Bonneville and BPA constructed transmission lines during wartime conditions represents a remarkable accomplishment. The additional paperwork required to obtain clearances from the National War Production Board compounded the problems stemming from the drastic shortages of materials and skilled labor. Moreover, the continuous revisions of construction and installation schedules strained the coordinating abilities of the two agencies to meet the accelerated war industry and defense establishment needs in the Pacific Northwest. At war's end, the Corps had installed all the planned power facilities at Bonneville Dam, and BPA had constructed a transmission system of 2,737 circuit miles of high-voltage lines and 55 substations. The efficient operation of the Pacific Northwest power pool conserved power equal to the output of an additional plant of 135,000-horsepower capacity, saving 3 million barrels of oil and great quantities of coal for other strategic war-time uses.

The aluminum industry became the first new industry attracted to the Pacific Northwest by the cheap power from Bonneville. ALCOA opened the region's first aluminum plant near Portland in 1940. Reynolds Metals Company began producing aluminum the following year in Longview,

Washington. Although the first two aluminum plants represented private investment, the federal government built the next four plants as part of the war effort and operated them through contractors during the conflict. These plants accounted for a significant portion of the nation's aluminum production. By 1943, the Pacific Northwest manufactured 622,000 tons annually, accounting for more than 25 percent of the national total of 2.4 million tons. Much of this aluminum was used in building military airplanes.

After the outbreak of war, the Boeing Airplane Company rapidly expanded production. At their peak, Boeing's Seattle plants employed 50,000 workers and turned out 16 planes every 24 hours. By war's end, Boeing had built 7,000 B-17 Flying Fortresses and 3,000 B-29 Superfortresses. In all, the aluminum plants, powered by electricity from Bonneville and Grand Coulee dams, produced material to fabricate 50,000 warplanes.

Electricity from Bonneville also powered the shipyards at Portland and neighboring Vancouver, Washington. Using 35,000 kilowatts of electricity, the Henry Kaiser shipyards turned out a Liberty ship a day for an extended period, ultimately producing 322 of the ships. These 441-foot long freighters carried food, arms, and supplies vital to the Allied cause. The yards also built 99 Victory cargo ships and numerous escort aircraft carriers, tankers, and other vessels. In all, the three Portland-area Kaiser shipyards built 750 ships for the war effort. This output represented 27 percent of the United States' total ship production during the war.

The Bonneville project also contributed to the Kaiser shipbuilding effort in other ways. Kaiser's shipyard organization, which introduced innovations in ship construction, was staffed largely by men who had worked for the contractor in building Bonneville Dam. Drawing on their earlier experience at Bonneville which required coordinated teamwork to accomplish many tasks within a tight time frame, Kaiser management developed a system for preassembling ship parts in different buildings and then bringing them together on the ways. In addition, the shipyards employed approximately 1,000 ship carpenters who had learned their skill while crafting the forms for the hull-shaped draft tubes used in the powerhouse at Bonneville.

While inspecting war production facilities in the Pacific Northwest during the fall of 1942, President Roosevelt visited the Kaiser shipyards at Portland. After witnessing the launching of the Liberty ship *Joseph N. Teal*, which had been built in just ten days, the President pronounced himself greatly heartened: "I am very much inspired by what I have seen, and I wish that every man, woman, and child in these United States could have been here today to see the launching and realize its importance in winning the war."

The Bonneville project also aided the war effort by facilitating the movement of war material and supplies. At a time when railroad cars were in short supply, barges carried grain, ammunition, and other essential commodities through the Bonneville navigation lock. The scale of this wartime traffic through the Bonneville lock can be seen by comparing previous tonnage with that of the war years:

Years	Average Tonnage
1930–39	113,906
1940–45	766,593

Tonnage shown for Bonneville project prior to 1938 represents traffic at Cascades Canal and locks about 3.5 miles upstream, which was inundated by the pool formed at the completion of Bonneville Dam in February 1938.

Shrouded in great secrecy, Bonneville Dam helped supply power to the Hanford Engineer Works. The top secret work at Hanford required a heavy electrical load, eventually amounting to 55,000 kilowatts. This so called "mystery load" equalled the entire output of one of the new units installed at Bonneville. Hanford employed this power to produce plutonium for atomic bombs.

Speaking at the December 1943 dedication of the final power unit installed at Bonneville, Major General David McCoach, Jr., prophetically stated: "This accomplishment will undoubtedly shorten the war and save many American lives." The total power production of Bonneville and Grand Coulee dams between 1939 and 1946 amounted to 33.8 billion

SECTION V

Military Construction Overseas

World War II forced Army engineers to begin planning construction on a worldwide basis. Projects awaiting both military engineers and construction firms they hired included depots and camps, roads and railroads, as well as ports and harbors. Engineers would work on these projects in weather that varied from arctic to tropical, and in terrain that included jungles, deserts, and mountains.

Engineer construction overseas began early in the war in the cold, damp climate of England. An invasion of the continent from England required a massive buildup of troops and that required depots, camps, and training sites. But the first priority was airfield construction to support the air offensive against Germany.

In the Middle East, the air war also required the support of the construction engineers. Air Transport Command service to that area and beyond required an expansion of the existing British and French facilities. The 38th Engineer Combat Regiment built an airfield on Ascension Island in early 1942 as part of the South Atlantic route. Construction engineers eventually built new fields or improved existing sites from Accra across central Africa to Khartoum and north to the Persian Gulf. There engineers had been hard at work since 1941 constructing a supply line to Russia through Iran.

As the war moved into Europe, construction engineers rehabilitated ports in the Mediterranean as well as along the French and Belgian coasts. To get supplies from the ports to the front, Army engineers rehabilitated the railroads as well as the roads and bridges of Europe.

In support of the war in the Pacific, Army engineers began work on a highway through British Columbia and the Yukon Territory to Alaska in March 1942. Despite problems with permafrost, mud, ice, and snow, the engineers took only eight months to complete the 1,450-mile pioneer road,

finishing on 20 November 1942. In Hawaii, Army engineers strengthened the defenses and increased the base facilities as troops and equipment were moved through to the western Pacific battlefields.

In the China–Burma–India theater, organized to provide material assistance to China, Army engineers built airfields, improved railroads, and increased the existing road system. As the Allies pushed into Burma, the engineers built a road through the Himalayas from India to China.

In both the Southwest and Central Pacific campaigns, the airplane played a vital role. Existing facilities were few, so the engineers had to carve the fields out of the jungle and coral. The B-29s that carried the atomic bombs dropped on Hiroshima and Nagasaki came from such a field on Tinian.

In World War II, a war of rapid movement over large areas, the construction engineers accomplished their mission under the greatest of difficulties. The following essays represent a few of the widely divergent overseas construction missions of the Army engineers. The first describes construction activities in the Persian Gulf Command that allowed lend–lease material to transit Iran on its way to Russia. One of the more difficult jobs, putting ports back in working order, is shown in the rehabilitation of the port of Le Havre. The final setting is the mountainous jungles of India and Burma where engineers constructed the Ledo Road into China.

The Persian Gulf Command: Lifeline to the Soviet Union

by Frank N. Schubert

In 1941, the Middle East was an obscure and remote corner of the world to the United States. Intelligence operatives in the War Department knew virtually nothing about the region. In fact, when questions first arose about possible operations in Iran, the best source of information proved to be the Library of Congress, where consultants on Islamic archaeology provided maps and information on roads and other transportation routes.

Other nations that were already embroiled in the war in Europe did not share American ignorance. In August 1941, Great Britain and the Soviet Union, longtime competitors for dominance in the Persian Gulf and Afghanistan, jointly occupied Iran, which seemed inclined to support Germany. The Soviets controlled the area north of the capital city of Teheran, Britain took the south, and they jointly held Teheran. The treaty that legitimized the division in September 1941 guaranteed Iranian neutrality for the duration of the war and the end of the occupation within six

His Royal Highness, the Shah of Iran (center).

months of the end of hostilities. The treaty gave Britain and the Soviets firm control of Iranian communications.

Although the occupation was designed to deny the area to Germany and its Axis partners, Iran turned out to be a positive asset to the Allies. The country provided a reliable supply route to the Soviet Union, which was reeling under the huge German offensive that started in June 1941, just when other routes, particularly the northern oceanic route from the Atlantic ports of the United States to Murmansk and Archangel, were proving very hazardous to Allied shipping. It was in the development and use of this critical supply line that American Army engineers came to play a major role.

The United States Military Iranian Mission opened its doors in September 1941. Under Colonel Raymond A. Wheeler, a career engineer officer who won fame later in the war for his work in the India–Burma theater, the mission set out to help the British by building supply facilities for their forces in the Persian Gulf and by assisting their efforts to support the Soviet Union. As the situation evolved, Wheeler and his successors concentrated on the latter job. Wheeler had the right credentials. A former engineer of maintenance of the Panama Canal and acting governor of the Canal Zone, he specialized in railroad and highway construction, both of which would be primary elements of American work in the region.

Initially, construction support for Wheeler's mission was assigned to the Corps of Engineers, which established the Iranian District under the North Atlantic Division for the job. Colonel Albert C. Lieber became the district engineer. He controlled the execution of engineer tasks, while Wheeler remained the final authority regarding which projects were carried out until the command developed its own construction service in 1943.

In 1942, Wheeler's office began an evolution that ultimately turned it into the Persian Gulf Command. Two months after Colonel Don G. Shingler replaced Wheeler in April 1942, the office was redesignated the Iran–Iraq Service Command, which reported to the Cairo headquarters of U.S. Army Forces in the Middle East. Then, in August, Shingler's office became the Persian Gulf Service Command. In a final

Major General Donald H. Connolly, (15 March 1948).

change in December 1943, the organization became the Persian Gulf Command and reported directly to the War Department in Washington. Like Shingler, Major General Donald H. Connolly, who took command in October 1942, and Brigadier General Donald P. Booth, who followed in December 1943, were engineer officers. All three were West Point graduates and had served in Corps of Engineers districts in the United States. Connolly, who ran the Persian Gulf Command during its buildup and peak operation, had directed New Deal work relief construction programs in Los Angeles during the height of the Depression and had been the Civil Aeronautics Authority head when the war started.

Iranian climate and topography represented severe challenges for road and railway builders. North of the Persian Gulf ports stretched a 175-mile-wide salt desert. Temperatures in the summer reached a searing 160 °F, and rain averaged 6 inches a year. Further north, the Iranian plateau was cut diagonally from the northwest to the southeast by mountains with peaks as high as 13,000 feet. Passes in the mountains were between 8,000 and 9,000 feet, and snow drifts of 7 to 10 feet blocked the roads in winter. Temperatures ranged from over 100 °F to below zero. At least the northernmost portion of the country adjacent to the Caspian Sea was temperate with only rare winter frosts, but overall Iranian climate and topography represented a much greater challenge than the relatively straightforward rail and road construction jobs themselves.

Even before the Americans arrived, the British understood that the Iranian State Railway held the key to the main supply route. The British hoped to raise the capacity of the single main line to the north tenfold, from 200 to 2,000 tons

per day, and to move an additional 12,000 tons a month toward the Soviet border by highway. The United Kingdom Commercial Corporation had charge of procurement and delivery of goods for shipment to the Soviet Union. This quasi-governmental British firm soon gave way. Within six months of American entry into the war, Iran became eligible for lend–lease assistance. By the end of 1942, the Americans in Iran had direct responsibility for the flow of supplies through the Persian corridor to the Soviet Union and an organization in Iran to carry it out.

From late 1942, the main concern of the United States in the Persian Gulf was transportation to the Soviet Union. The Germans were inflicting heavy losses on Allied shipping to the Arctic port of Murmansk, and the Red Army was fighting desperately to throw back the Germans at Stalingrad. These developments underscored the need for a secure supply route that was open all year. To assure such access from the Persian Gulf, the principal land routes from the Gulf were the keys. The ports of Ahwaz, Khorramshahr, and Bandar Shapur in Iran and Basra in Iraq had capacities far beyond that of the railway and road. "It was obvious," T.H. Vail Motter, author of the official history of the Army's work in the Persian Gulf, wrote, "that substantial backlogs would accumulate at the ports until inland clearance could be brought into balance with port capabilities."

The main highway north from the Persian Gulf extended 636 miles from the port of Khorramshahr to Kazvin. Substantial portions of the southernmost 172-mile leg to Andimeshk were completed in 1942. First the engineers finished a temporary highway, resurfacing a stretch of desert track that generally paralleled the railway. Then alongside they started an all-weather 24-foot highway that gradually sloped up across the desert from Khorramshahr at an altitude of 10 feet to Andimeshk at 500 feet. The constructors faced dust storms in the summer and heavy rains in the winter.

Delays came from many causes. Equipment shortages, exacerbated by the occasional sinking of vessels—such as the *Kahuku*, which went under near Trinidad with 7,480 tons of supplies destined for Iran in June 1942—were always severe. The worst shortages involved rollers for compaction and the absence of good base course materials for the southern

segments of the road. The design took these scarcities into account. The southern section was built on an earthen embankment that was scraped, sprinkled, and compacted with sheepsfoot rollers. Further north, around Ahwaz, builders used local sandstone over an earth embankment. Beyond there, gravel was available. For the entire length of the highway, the subgrade was sealed with cut-back asphalt and covered with a 2-inch mat of soil asphalt. Although concrete was hard to find in Iran, asphalt was readily available from the oil refineries at Abadan.

With some segments still incomplete, the southern desert stretch of the highway experienced a major flood in the spring of 1943. Two bridges and 8 miles of road were completely washed out, and a 30-mile section had to be rebuilt. In the haste to finish the job, specifications calling for a 10-foot elevation above the desert floor were ignored and the number of culverts was reduced. When the rains came, the rivers overflowed, and soon the road was in a 200-square-mile lake with 3-foot waves lapping against the embankment. "One day," Waldo Bowman of *Engineering News–Record* wrote, "the job was in a dust bowl and 24 hours later it was merely a causeway across a lake." The road to Andimeshk was finished in 1943, rebuilt largely by troops of the black 352d Engineer General Service Regiment, who arrived 1,325 strong at Khorramshahr in March 1943, just in time to take on the project.

Much of the road to Andimeshk had been built for the district by civilian contractors. But a transition to a military work force was underway by the time the next leg to the north started. The change was due generally to the entry of the United States into the war and the threat to the Persian Gulf from Axis armies operating in North Africa. Specifically, the security situation in Iran north of Andimeshk was uncertain. The nomads of the plateau and mountains were less friendly than the people of the south. The War Department militarized all overseas construction contracts in the last four months of 1942, and the contract with Folspen, a combination of Foley Brothers and Spencer, White, and Prentis, was converted at the end of the year. By then, Folspen had made a major mark on the program. The firm had completed much of the southern portion of the highway and solved a critical supply shortage by suggesting importation of steel girders

from the newly demolished Sixth Avenue elevated line of New York City.

The transition to a military work force eliminated the need for a contracting office to manage the operation of civilian firms and brought the end of the Iranian District in May 1943. The Persian Gulf Service Command divided its vast area of responsibility—it was about the size of Texas and California—into three districts of its own. After a brief time in which a commandwide construction service operated in all three districts, the districts themselves took over construction, much like the Corps of Engineers.

Within a month of the dismantling of the Iranian District, the engineers and British forces began work on the road from Andimeshk to Kazvin. The 334th Engineer Special Service Regiment, augmented by Iranian civilian workers, converted the extant rough road between Andimeshk and Malayer into a highway adequate for truck convoys. This regiment, which was activated at Camp Claiborne, Louisiana, in mid-1942, was one of two such units in Iran, along with the 363d. The Office of the Chief of Engineers had tailored these regiments specifically for construction assignments with a larger number of skilled construction machinery operators in senior noncommissioned grades than conventional general service regiments. The 334th started out with its companies divided between the port of Khorramshahr, the highway, and the American base camps at Ahwaz and Teheran; but in July 1943, the entire regiment went to work on the Andimeshk–Malayer highway, including construction of a 240,000-gallon water reservoir near Andimeshk.

Theirs was a big job. Beyond Andimeshk were rugged mountains and deep gorges with abrupt and steep 10 to 12 percent ascents. Badly paved in places and elsewhere not surfaced at all, the road itself was a great hazard to those who sought to straighten its curves, reduce its hills, replace its surface, or relocate the worst stretches in 1943. The road was desperately needed. Until the pavement was completed, driving the highway with its many miles of washboard was an ordeal. One soldier wrote as the work was getting underway in the summer of 1943 that "vibration shook the trucks to pieces, broke off gas tanks, and pounded the men's kidneys to jelly." Overall, the Americans built 250 miles of the road to Kazvin; the British built 200 miles.

A Persian Gulf Command service road bridges a gorge at Talehzang, north of Dezful. *(Donald Connolly Collection, Office of History, Corps of Engineers)*

Bridges on the main highway were all permanent. They were designed to make use of whatever materials were available. Because the old salvaged steel beams came in various sizes, bridges were designed to fit the beams, rather than the other way around. All fabrication was done on site, with extensive electric welding. Abutments of gravity type mass concrete were placed, while piers, beams, and deck slabs were formed of reinforced concrete. Decks themselves were 26 feet wide between curbs.

Work on the main highway was just getting underway when the first American railroad troops started to arrive in Iran. The 711th Engineer Railway Battalion was created at Fort Belvoir, Virginia, in June 1941 from portions of other engineer units and recruits from the Engineer Reserve Training Center there. The 711th was the first railroad operating battalion assembled during the war and was unlike later units of the same type, which were sponsored by specific railroads and consisted mainly of employees of those lines. Before the 711th arrived in the Persian Gulf, it and the other battalions like it were taken from the Corps of Engineers and assigned to the new Transportation Corps. But when it was organized, it was an engineer unit commanded by Lieutenant Colonel Marshall J. Noyes of the Corps of Engineers.

The Iranian State Railway represented quite a challenge for those who were expected to increase its capacity ten-fold. Its north–south standard-gauge main line, according to Lieutenant Francis J. Lewis, who wrote the official history of the military railway service in the gulf, combined "in fantastic concentration practically every conceivable phase of engineering and railroad construction." Built between 1926 and 1939, "it was a fantastic railroad," with 3,000 bridges, 231 tunnels, and a range of 7,400 feet in altitude. The line was vulnerable to falling rock, floods, snow, rain, and drifting sand. But the Persian Gulf Command was up to the challenge. In fact, in its last two years of operation, the railroad far surpassed the goal of 2,000 tons per day and averaged 3,397. During the peak month of July 1944, a prodigious 7,520 tons of equipment and supplies went up the line to the Soviet Union every day.

A ceremonial train carrying the 3-millionth ton of lend–lease aid to the Soviet Union leaves a Persian Gulf Command rail yard. *(Donald Connolly Collection, Office of History, Corps of Engineers)*

The railroad remained the primary lifeline to the Soviets, "the ready-made steel backbone of the Iranian supply line," according to the official command history. Still, the highway provided an important auxiliary route. The availability of parallel truck and rail lines created options when one or the other was not usable. When the floods disrupted highway

traffic in the spring of 1943, trains carried all goods from Khorramshahr to Andimeshk, where they were transferred back to trucks.

Under an agreement with Britain signed in July 1943, Engineer troops kept the road open from Khorramshahr to Kazvin, in spite of floods, rock slides, and snow storms. The 352d General Service Regiment did much of this work. Within a month, the regiment was strung out between Khorramshahr and Andimeshk, keeping the road clear. One company drove trucks north, another operated sand and gravel pits for the entire command, and the other four repaired the highway, which took a continuous beating and needed regular attention.

Other construction supported the main effort on the transportation routes. The first projects concentrated on the expansion of the ports. At the docks on the gulf, as with the roads, shortages of equipment and materials led to improvisation and the search for supplies. For example, the long piles that were needed for jetties in the extremely fluid coastal soils were spliced together from teak piling purchased in India. Later came the vehicle assembly plants at Khorramshahr and Andimeshk, where trucks destined for service in the Red Army were put together from major components shipped from the United States.

A group of U.S. senators inspects Iranian waterfront installations developed to speed the flow of American supplies to Russia. *(Office of Technical Information)*

After these operational facilities came lower priority projects, with barracks, hospitals, mess halls, and latrines taking precedence over administrative buildings and service clubs. The command built its headquarters at Amirabad, on the rising ground between Teheran and the mountains, and a major railroad–highway transshipment base that included ordnance workshops and camps for 3,000 at Andimeshk. In these facilities too, improvisation was the order of the day. With timber so scarce, troops assembled roofs from boards stripped from the beta-pack crates in which truck components had arrived at assembly plants. These were nailed on slender ballie poles cut from the ever-present silver-leaf poplar and covered with locally made tar paper and a sand–asphalt mixture.

At every step, operations were hampered by the extreme weather in what Joel Sayre of *The New Yorker* called "that queer drear, roasting land of Iran," and by the theft of an estimated 250 miles of copper communications wire for conversion into bazaar trinkets. Despite the obstacles, by the end of 1943, a total of 36 posts, housing nearly 30,000 American troops, and 44 airstrips dotted the landscape. The structures at these camps were unusual: because of the availability of kiln-fired mud bricks and the scarcity of timber, buildings in the Persian Gulf theater were among the few permanent structures built by engineers during the war. The bill for the construction work totaled nearly $100 million.

The work of the soldiers of the Persian Gulf Command did not capture headlines. In fact, they called themselves the FBI, the "forgotten bastards of Iran." But despite the obscurity in which they worked, their efforts had a significant impact on the war.

Globally, five routes funnelled war supplies from the western Allies to the Soviet Union. The line from American Pacific ports to Siberian harbors on the Arctic Ocean and the Black Sea route available after Axis navies were cleared from the Mediterranean Sea were the least important. Next came the Atlantic routes to the North Russian ports of Murmansk and Archangel. Only the sea lane from the Pacific ports of the United States to eastern Siberia carried a greater tonnage than the Persian Gulf route. The Japanese navy ignored this traffic, but because of this route's vulnerability, it only carried nonmilitary supplies.

Over 4 million tons of war supplies went to the Soviet Union from the Persian Gulf. Open all year and relatively safe from enemy interdiction, the gulf provided the largest lifeline for military equipment and supplies. The vast amount of material that went north from the gulf included nearly 45 percent of the 400,000 lend–lease trucks of American origin that were given to the Soviets. As T.H. Vail Motter, the official historian of the Persian Gulf Command, noted, "the significance of the Persian Gulf route is measured by its tonnage accomplishment and its fulfillment of strategic necessity."

Sources for Further Reading

This article is based largely on T.H. Vail Motter, *United States Army in World War II. The Middle East Theater. The Persian Corridor and Aid to Russia* (Washington, DC: Office of the Chief of Military History, 1952).

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Reconstruction of Le Havre

by Barry W. Fowle

The logistic support to the United States forces on the European continent reached its lowest ebb during October 1944. Bad weather had an adverse effect on operations at the beaches and also prevented the use of shallow-draft shipping to the smaller ports. Cherbourg was far from complete, and the small Brittany ports made only a modest contribution to total needs. In the first three weeks of October, loadings averaged less than 25,000 tons per day against an estimated requirement of 40,000.

The supply problem would not be solved until Antwerp opened in December, but the situation took a turn for the better in November. The improvement was in part due to overcoming the clearance problem at Cherbourg. More important was the opening of two new ports, Le Havre and Rouen, which lay at least 100 miles nearer the front lines than did Cherbourg. Both ports were in operation by mid-October, making it possible to close all the minor ports in both Normandy and Brittany except two, Granville and Morlaix.

Le Havre was the most thoroughly demolished of the continental ports. Its damage exceeded that of Cherbourg and Brest. All of its locks were inoperative. The portion of the port served by the tidal basin was not usable. Every deep-water berth was destroyed by German demolition, and debris was piled upon the damaged structures by the collapse of buildings hit by Allied bombing. The heart of the city, an area of approximately one square mile, had been almost completely demolished by Allied bombers.

There were a number of obstructions to navigation in the harbor. A floating dry dock and two vessels were sunk across the entrance to the harbor. Numerous barges and other small craft were sunk throughout the majority of the basins. Although reports from prisoners indicated there was no extensive mining of the port, several controlled minefields were found, and large numbers of mines were located in other areas. All the locks in the port were damaged to some extent with damage confined to the gates themselves.

Most of the cranes were badly damaged and could not be readily repaired. The major warehouse and storage facilities were hard hit, but many frames still stood on which sides and roofing could be placed.

Debris blocked roads and bridges, and several of the bridges over the locks needed repair or replacement. The marshalling yards were relatively undamaged, but a few bomb craters existed. Tracks in the vicinity of the quays were obstructed by debris or damaged from bombing. Most of the railroad bridges over the locks and the important rail bridges over the Tancarville Canal were heavily damaged.

The 373d Engineer General Service Regiment, commanded by Colonel Frank F. Bell, was placed in charge of all units assigned to reconstruction of Le Havre. Units at the technical disposal of the 373d included: the 351st Engineer General Service Regiment (1st Battalion), the 1055th and 1061st Port Construction and Repair (PC&R) Groups, the 577th Dump Truck Company, the 392d Engineer General Service Regiment, the 1593d Utilities Detachment, and two companies of British marine engineers.

The mission of the engineers at Le Havre had four parts. The first two called for developing the port to a daily capacity of 4,000 tons by lighterage and 2 1/2-ton amphibious trucks (DUKWs) in the shortest possible time and determining the maximum tonnage which could be developed by lighterage and DUKWs. The rest of the mission involved determining the practicality of employing coasters and the feasibility of reconstructing port facilities to provide full deep-water berths within a reasonable time. Since economy of time was an important factor, the engineers constructed a number of new deep-water quays rather than restore the demolished quays which were covered by thousands of tons of debris.

The rehabilitation of Le Havre—the second largest port in France—was a complex and varied task. It included road construction and maintenance; clearance of beaches; rehabilitation of water sewage systems; repairs to an airport; docks, jetties, and quaysides; salvage of sunken vessels; reconstruction of lighting facilities; repair of old and building of new POL (petroleum, oil, and lubricants) and warehousing facilities; mine and booby trap clearance; and construction of

Company D, 373d Engineer General Service Regiment blows German concrete barges underwater. Staff Sergeant Thomas Atchison detonates the charge, Le Havre, France, 1 October 1944.

expedient berthing facilities. In addition, supplies which were to be landed at Le Havre required a network of roads and streets that connected with the White and Red Ball highways serving the front lines.

The first phase in the reopening of the port was the establishment of beaches to accommodate landing ships, tank (LSTs), landing craft, tank (LCTs), and landing craft, medium (LCMs). Engineers had to first sweep the beaches for mines and then remove numerous obstacles. The Germans had strewn tetrahedrons around the beach and built anti-landing ramps at the low tide mark. They also sunk huge reinforced concrete barges filled with debris to prevent the use of the beach by landing craft. On the high tide portion of the beach, the engineers had to remove walls and blockhouses.

The 1st Battalion, 373d Regiment, formed a special mine deactivation group that included two men from Headquarters and Service Company. First Lieutenant John K. McGrath, Company A, and Sergeant William G. Lockwood—later second lieutenant—were in charge. The regiment assigned this group the task of clearing the beach, the entire dock area of the city, and numerous buildings and areas in other locations, making them safe for occupancy by military personnel.

They were also responsible for clearing gun positions for several antiaircraft units. By 15 October, the group had deactivated over 1,100 mines.

The French, under the supervision of the 373d Regiment, assisted the special deactivation group. They were responsible for removing mines and booby traps from areas of Le Havre that had no bearing upon military operations in the city. Lieutenant McGrath assigned Sergeant Lockwood the task of instructing these civilians in the procedure of removing mines and booby traps, and for a period of several weeks supervised their work. Monsieur Lepape Robert, later killed by a mine, was the foreman of the French deactivation unit which deactivated almost 1,000 mines of different types, mostly antipersonnel and glass mines. In total, the 373d removed over 1,500 mines and bombs.

When the 373d arrived at Le Havre, practically no work had been done on the streets. The unit literally had to bulldoze its way in to make a reconnaissance of the beach areas. The engineers began road opening and clearance on 20 September, first clearing the streets leading to the beaching spots for LSTs. In order to utilize the dock area, its roads and streets had to be made passable with connections established to the White Ball Highway serving the front lines.

Before: The 373d Engineer General Service Regiment has placed demolition charges and partially sandbagged the reinforced concrete road block, Rue de Croix, Le Havre, France.

After: Results of the blast on the road block (see previous photograph).

In order to establish storage and transfer points adjacent to the beaches, the 373d cleared barbed wire defenses, trenches, mines, and other antipersonnel devices from the area. The clearing of the beach areas progressed sufficiently to allow entry of a few vessels on 2 October. Brigadier General William M. Hoge's 16th Port Command, just arrived from Brittany to take over port operations, unloaded these vessels.

Once the engineers established the LST beaching areas in the Avant Port sector, installation of the first DUKW ramp on Mole Central began, followed by the installation of three DUKW landing areas on Mole Oblique.

Prior to the repair of lock gates at the seaward end of the basins by the 1055th and 1061st PC&R Groups, units under the 373d established berthing facilities for four Liberties with a floating pier constructed at the base of Mole Oblique. Attached to the 1055th was the 1071st Engineer port repair ship, the *Junior Van Noy*, which performed a multitude of tasks including diving operations, underwater burning, sounding with a depth finder, general machine shop work, welding, and blacksmithing.

On 13 October, crews unloaded three Liberties. After that, discharge improved rapidly. In the first full week of operations, Le Havre discharged about 2,000 tons per day. In the

second week, the average rose to 3,650 tons, double that expected. By 23 October, Le Havre's target was increased to 9,100 tons within the next 30 days, exclusive of POL and coal. The discharge rate averaged 5,000 tons within a week. Since the expected opening of Antwerp was rapidly fading with the failure to secure control of the channel to the port, the Communications Zone raised Le Havre's target to 9,500 tons by 1 December. That amount was actually being exceeded by the end of the month.

During this phase of the development of the port, the 373d gave the 1055th and 1061st Engineer PC&R Groups, plus the two British marine engineer companies, the assignment of removing underwater obstructions in the basins and canals, repairing locks, and doing other specialized work for which their personnel and equipment fitted them.

The most important repair work required for the operation of the port was to the locks of the two entrances leading to Basin de L'Eure, the main basin. These entrances kept the water level in the basin at the high-tide level of 25 feet. Through the gates to the main or southern lock, vessels as big as Liberties and larger could enter or leave at any stage of the tide. Within the basin the ships moved about freely, unloading continuously without concern for the water level. The Germans took special pains to render these two locks useless.

There were four gates, or leaves, to the main lock, two outer and two inner, swinging on hinges like a door. Each weighed 275 tons. The Germans had blown the south inner gate off its hinges. The engineers towed it to a dry dock for repair by a French contractor. Repairs included rebuilding the 2-ton bottom hinge, requiring the fabrication of several new pieces and the straightening of some old pieces.

When the workers put the leaf back, a forged steel collar around the upper hinge pin broke, letting the gate drop forward. To keep the leaf from toppling over completely, operators admitted and expelled water from the ballast compartments, holding it in place. A 60-ton floating crane helped pull the gate back into position. Loss of the gate would have delayed the opening of the harbor by at least a month.

Actually, the gate was out of service only 60 hours. Colonel Bell devised a scheme to replace the forged collar with one

flame-cut from a slab of 6-inch armor plate, and French workers fabricated it. The flame case-hardened the manganese steel plate, preventing it from being machined. But it worked until the engineers could obtain a new forged and machined collar.

Replacing the south outer gate was not without problems either. Underwater demolition charges had badly damaged the gate, but it was still on its hinges. Workers estimated the time to repair the gate at several months. Fortunately, crews found a gate to fit the opening and put it into temporary service.

The second entrance to the main basin, adjacent to and north of the first entrance, was also essential to the functioning of the harbor as a series of wet docks. The Germans had suspended a demolition charge about 10 feet underwater on the center line of the gate where the two leaves came together. It blew a 40-foot hole, half in one leaf, half in the other. The charge ripped out much of the structural framing of the leaves, making them impossible to move. The only method of repair was to make them tight with a patch of some type, so they could serve as a dam controlling the tidal flow. Six 1-inch steel plates were used, stiffened with steel I-beams.

This arrangement still allowed too much water through the gates, so the cracks were patched with bags containing a mixture of 10 percent cement and 90 percent sand. To hold them in place, engineers piled a 1,500-cubic-yard rubble fill against the back of the gate. Workers used 3,500 bags.

Repair of the gates permitted ships to move about through the basins and discharge their cargo, but until the workers restored the key bridges, the unloaded shipments could go no further. The Germans had damaged all of the bridges. Four required replacement structures, and the Army provided Bailey bridge spans. In addition, the engineers built a unit construction railroad bridge (UCRB) at the lock separating basins Fluvial and Vetillart. Crews installed three of the Bailey bridges in the usual method, assembled on the bank, then pushed across as a cantilever. Two were small, with only 70-foot spans, while a third, a triple-single, had a 120-foot span.

The fourth Bailey was collocated with the UCRB. Because both were vital to port operations, they were built quickly—in

nine days. Soon after construction, the work load required that the two bridges be converted to lift spans to allow larger craft to pass under them. Workers installed gantry frames and hoist platforms at either end of the bridges. To support the additional weight, the engineers installed additional pile substructure. A 4-ton gasoline engine furnished the power to raise the 35-ton UCRB and 20-ton Bailey through a 13-foot lift which took about 4 minutes.

As military activity increased in the port, engineers extended the road network. This required that various bridges across the Tancarville canal system, exiting from the rear of the port, be repaired in addition to bridges at various other basin and lock crossings. Depots established in the area of the Schneider works east of the city called for the repair of roads in that sector and the placing of additional bridges across the canal.

The engineers erected cranes in order to unload ships coming in to harbor. They constructed the first one at Basin Dock on 18 December, installing the English type traveling gantry crane. By 2 March 1945, engineers had constructed six of them.

POL facilities were available in the area of Basin Vetillart with a pipeline running to a ship-to-shore pumping station adjacent to the Seine. They had suffered from the Allied bombing and not only were badly in need of repair, but were inadequate. Engineers constructed additional facilities. They laid new pipelines, constructed a decanting area, built a new tank-filling area, and installed new pumping stations. The storage capacity was 90,000 barrels.

To make the POL facility operational, the 373d had to repair the narrow gauge railway line which ran along the same area as the pipeline. It cleaned and overhauled the locomotive and train, and relaid the 1½ miles of track.

Located at Le Havre was Fort St. Addresse, situated on the high ground overlooking Port Le Havre and the sea. It had been a French garrison, but the Germans converted it into a strong point of the city's defenses. The U.S. Army used it as a reinforcement depot, then converted it into a leave center for personnel returning home. Company A, 373d Regiment, got the mission of rehabilitation and conversion of the fort to a center capable of handling 3,000 men.

In order to take care of the many liberated prisoners of war, the 373d gave Company C the mission of constructing a tent camp at the Le Havre airport that could accommodate 2,000 personnel. In 2½ days, assisted by prisoner of war labor, the camp and utilities were ready for use. Later the engineers added improvements such as walks and water tanks.

The rehabilitation of the port also called for the installation of lighting. Company D, 373d, got all the projects for lighting. They provided lights to the dock areas, railway yards, warehouses, dwellings, and other structures by repairing existing systems. In some instances the engineers installed completely new wiring systems and poles.

When the 28-inch water main supplying the city collapsed in February 1945 due to tidal action, the engineers quickly repaired it. Engineer personnel supplied water to the U.S. Navy and Allies by repairing a bombed-out system on the island Digue Est. The regiment kept the system in operation despite difficulties. It also installed and operated three other water points for military use.

The cold storage facilities in Le Havre lacked sufficient capacity resulting in a need for additional space. The 373d and French contractor personnel solved this problem by cooperating in the reconstruction of a refrigeration plant on Mole Oblique to augment port facilities. Company D, 373d, provided the needed supplies, supervised the prisoners of war, did rehabilitation work, and provided the technical expertise.

A historic event occurred when the 373d assisted Western Union in the reestablishment of cable service. The Germans had destroyed the landward sections of the transatlantic cables serving the city, and Western Union wanted to put them back into service. The Second Battalion deactivation group aided in the restoration by clearing mines in the beach area where the severed cable came ashore. Under the supervision of the Western Union representatives, Company D winched the cable ashore, dug a ditch, and placed the cable in it.

From 1 November to 31 December 1944, Le Havre saw a tremendous transition. It went from a battered port limited to LST beaches and DUKW ramps to large-scale utilization

of the basin system of the harbor. With basin gates repaired and essential bridges replaced, Le Havre was once again operational despite its war-wrecked state. The results—fulfilling and even exceeding the programmed tonnage for the port—were a tribute to the ingenuity, speed, inventiveness, and perseverance of U.S. Army engineers. Although they only succeeded in patching up the harbor with temporary facilities, it did support the front line troops until Antwerp and Ghent were put into service.

Sources for Further Reading

Much of the material in this essay comes from *The 373d Engineer General Service Regiment in World War II* (Dallas: Corbey Company, 1947). Roland G. Ruppenthal, *United States Army in World War II. Logistical Support of the Armies.* Volume II (Washington, DC: Office of the Chief of Military History, 1959) and Waldo G. Bowman, *American Military Engineering in Europe from Normandy to the Rhine* (New York: McGraw–Hill Publishing Co. Inc., 1945) were also helpful.

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The Ledo Road

by James W. Dunn

The United States began to help China defend itself against Japanese aggression even before the attack on Pearl Harbor. President Franklin Roosevelt approved lend–lease aid for China in April 1941, and in June the United States began sending fighter planes, spare parts, and gasoline. The War and Navy departments also released over 100 pilots to form the American Volunteer Group, popularly called the Flying Tigers. A month later, the War Department established an American military mission to oversee the aid.

Approving aid to China was one thing, but getting it there was another. Japan had already seized China's coastal provinces and the Japanese move into northern Indochina in September 1941 had cut the railroad from there to Yunnan Province. That left the route from Rangoon in Burma to Yunnan as the only land supply line available to the Americans. When the Japanese threatened that route, Brigadier General John Magruder, the United States lend–lease administrator in China, sent engineer Major John E. Ausland to look for an alternate route to China from India through northern Burma. Ausland reported that the terrain there was very difficult, especially in the Patkai Mountains along the Burma–India border.

When America's entry into the war brought a request from Generalissimo Chiang Kai-shek for an American general officer to be his chief of staff, the United States sent Lieutenant General Joseph W. Stilwell. He was also named Commanding General of the United States Army Forces in the China–Burma–India theater of operations (CBI). It was as chief of staff that he first got involved in theater operations.

The Japanese seized Rangoon in March 1942 shortly after Stilwell arrived, and Chiang sent Chinese troops into Burma. He asked Stilwell to coordinate their use with the British, who were responsible for the defense of the area. This first Burma campaign was a losing effort.

The Ledo Road

Stilwell walked out of Burma in May 1942 bringing with him to India the remnants of two Chinese divisions. He still had the mission of supporting China, but he no longer had a land supply line; the Japanese offensive had cut the Burma Road. Stilwell would have to clear a path for a new road right through the terrain Major Ausland had found so difficult. Only now there was an additional challenge; the Japanese occupied most of the terrain.

By the fall of 1942, Stilwell had a plan. The British agreed to a North Burma campaign to clear the road route and assigned the area to Stilwell. In November Chiang Kai-shek approved the use of the Chinese forces and named Stilwell their commander. General George C. Marshall, Chief of Staff, U.S. Army, promised Stilwell priority for troops and equipment second only to the North African campaign, but soon found he could not keep that promise.

General Stilwell's operations officer, Lieutenant Colonel Frank D. Merrill, recommended building a road from Ledo in Assam Province, India, south and east across northern Burma to a junction with the old Burma Road. The new road would support a North Burma campaign and, when linked with the old, provide a land supply line to China. Merrill chose Ledo because it was near the terminus of the rail line from Calcutta and was at the northern end of a caravan route out of Burma. The concept was for U.S. Army Engineers to build a road generally following the caravan route from Ledo south through the Patkai Mountains and the Hukawng and Mogaung valleys, to connect with the old Burma Road east of Bhamo.

The proposed route for the road went through some of the most difficult terrain in the world. The triangular-shaped territory of northern Burma included jungle-covered mountains and swampy valleys. It was virtually uninhabited with the major towns being nothing more than frontier posts. The mountains, offshoots of the Himalayas, were formidable land barriers that rose to heights of 8,000 to 10,000 feet. The Hukawng and Mogaung valleys were tropical rain forests, dark and silent, with matted undergrowth where the clearings were really swamps covered with elephant grass 8 to 10 feet tall.

According to Dr. Gordon Seagrave, the famed "Burma Surgeon," this unattractive area was the ancestral home of the leech. He found three major types: big brown ones on the ground, red ones in the elephant grass, and green on the tree branches. While the leeches were pests, the malaria-bearing mosquitoes and typhus-carrying mites could be deadly in the absence of strict preventive medicine measures.

There are two seasons in northern Burma, wet and dry. The wet monsoon season lasts from May to October when the rainfall is heavy, averaging 140 inches in the mountains and 120 inches annually in the valleys. By comparison, the east coast of the United States gets about 45 inches in a year. Although the monsoon season produces hot, humid weather, the dry season is a very comfortable period of California-type weather.

While the terrain and weather were formidable barriers for the engineers to overcome, the enemy initially posed less of a problem. After the Japanese conquered central Burma

in early 1942, they consolidated their position during the monsoon season and did not move forces north of Myitkyina. Lieutenant General Renya Mutaguchi's veteran 18th Division, conquerors of Singapore, outposted the area but made no movement north in the Mogaung Valley.

The Chinese troops, who would face this Japanese force in the North Burma campaign, began training in India in the summer of 1942. To support them, General Stilwell organized a Service of Supply (SOS) under the command of Major General Raymond A. Wheeler. Stilwell had known Wheeler as one of his language students at West Point and had developed a high opinion of his engineering abilities. A career Army engineer, Wheeler had won recognition as a road-builder while commanding the 4th Division's engineers in the Argonne Forest campaign in World War I.

Stilwell made SOS responsible for construction in India and Burma. In response to Wheeler's request, the War Department sent him the 45th Engineer General Service Regiment and the 823d Engineer Aviation Battalion. The two units arrived at Karachi, India, in July. They did not have any of their equipment and had to use lend–lease stock earmarked for China, but they were on the ground, in the theater.

Wheeler established Base Section 3 at Ledo, made it responsible for building the road, and named the 45th Regiment's commander, Colonel John C. Arrowsmith, as base commander. Arrowsmith had his own 45th Regiment and the 823d Engineer Aviation Battalion begin the road project, putting them to work first building warehouses, hospitals, barracks, and base roads at Ledo. On 16 December 1942, they began building the double-track, all-weather Ledo Road. The 823d cleared a road trace and the 45th followed completing the grading and applying a metaling stone (any substance, usually natural gravel or crushed rock, used to stabilize a road surface in wet weather) to the roadbed.

The 45th began work with six D-4 bulldozers and no blades, but it managed to borrow one from a British engineer unit. As a result, the first part of the road was rather winding as the D-4 was too light for the rugged terrain and had to detour around obstacles. The 45th was also short of heavy rock crushers, but it did have 11 portables which it set up at the Tirap River near Ledo.

Bulldozers clear a slide in Burma, as engineers construct the Ledo Road.

By the first of the new year, the engineers were working around the clock and making good progress. The 823d's full complement of equipment had finally arrived and the unit pushed forward rapidly toward the Patkai Mountains. As it moved into the hills, progress slowed due to the difficult terrain. Continuous use of equipment without periodic maintenance and a shortage of spare parts contributed to the slowdown.

In February 1943, the engineers reached Pangsan Pass where rock outcroppings caused the 823d to increase its use of explosives. In one case, it was necessary to place charges 30 feet up a perpendicular rock face. Here one engineer hung by a rope lowered from the top to place dynamite that another engineer tossed up to him; an efficient but dangerous technique.

Through February, the 823d pushed for the India–Burma border. Company A broke trace, Company B put in culverts, and Company C widened and ditched the roadway. Only construction vehicles were allowed in the forward area. When Private Morris Humphrey stopped the SOS commander's jeep, General Wheeler commended him for carrying out his orders and walked the 2 miles to the roadhead. From long experience "Spec" Wheeler knew the ways and whims of engineers.

small columns from the 18th moved north up the valleys from Myitkyina toward the Patkais and the Ledo Road. The Japanese had trouble with the terrain, and air strikes caused the contractors who provided the elephants for the pack trains to desert with their animals. Short of supplies, the Japanese withdrew south.

As the immediate Japanese threat subsided, General Stilwell in April moved the Chinese 38th Division from India into the northern Hukawng Valley. He there established the headquarters of the Chinese army in Burma which assumed, from SOS, tactical responsibility for the forward area, the path for the Ledo Road.

During the early monsoon, March to May, the road moved only 4 miles. The Japanese threat and monsoon rains were part of the problem but so too was a lack of maintenance. Constant use of equipment, a shortage of spare parts, and the lack of trained supply personnel resulted in significant downtime. By the time the 479th Engineer Maintenance Company arrived in May, two-thirds of the tractors and one-half of the trucks in the 823d Battalion were out of service. The 45th Regiment was in much the same shape with one-half of its tractors and two-thirds of its trucks down.

The situation on the road continued to deteriorate through the monsoon even as the engineers applied unorthodox solutions to the maintenance problem. Lieutenant Leo A. Vecellio, who had worked for his father's east coast construction firm before the war, borrowed a cargo plane to bring a load of spare parts from Lahore, India, to the 823d. He then located a tea planter's foundry where it was possible to forge and weld other spare parts.

Additional help came in the form of reinforcements. The 456th Engineer Depot Company arrived in March, and in May the 330th Engineer General Service Regiment came in and went directly to the roadhead. Even though one battalion was assigned to airfield construction in India, the arrival of the 330th had an immediate impact on the road situation.

The first thing it did was free the 45th and 823d for some welcome rest and relaxation at the Howrah rest camp in Calcutta. The 330th was full of experienced engineers and construction men. The commanding officer, Colonel Charles S. Gleim, was a construction engineer from New Jersey and had

supervised the building of the Lincoln and Holland tunnels as well as the George Washington Bridge across the Hudson River. Major Edmund H. Daves, Jr., commander of the 2d Battalion, had been a corporal in the 12th Engineer Combat Regiment in the American Expeditionary Force in World War I and was a railroad construction engineer between the wars. Many of the men were skilled hands from contracting firms and construction gangs in the Middle West. The experience factor paid huge dividends, and the 330th became one of the most reliable units on the road.

More help came when a visitor from the States overstayed his temporary duty but not his welcome. In June 1943, Captain Eugene R. Nelson arrived on a liaison visit from the Engineer Field Maintenance Office. He found the solutions to the spare parts requisitioning, storage, and distribution problems so time consuming that he did not get out of the theater until he rotated in the summer of 1945. Nelson determined that distribution suffered from a lack of trained personnel and accountability while a lack of space caused the main storage problem. Requisitioning troubles were caused by a system that was too formal.

The first thing he did was conduct an inventory which improved the stock records system and accountability. He changed the system to allow an equipment operator to obtain parts without a formal requisition, conducted a training program, and recommended storage space expansion.

However, such successes were limited and not always timely. From May to August, the road advanced only 4 miles. Eager to get through the Patkais by the end of the monsoon, Stilwell sent Colonel Merrill to Ledo to find out what was wrong. Merrill's June report detailed all the problems of supply, maintenance, and weather but was nonetheless highly critical of recently promoted Brigadier General Arrowsmith and the lack of organization on the road. In August, Stilwell went to look for himself, and he determined that Arrowsmith was not the one to aggressively push the road ahead against all obstacles. He asked General Wheeler to replace him with a "top-flight" man from the States. Wheeler obtained Colonel Lewis A. Pick.

A graduate of the Virginia Polytechnic Institute, Pick had commanded an engineer roadbuilding company in the Allied

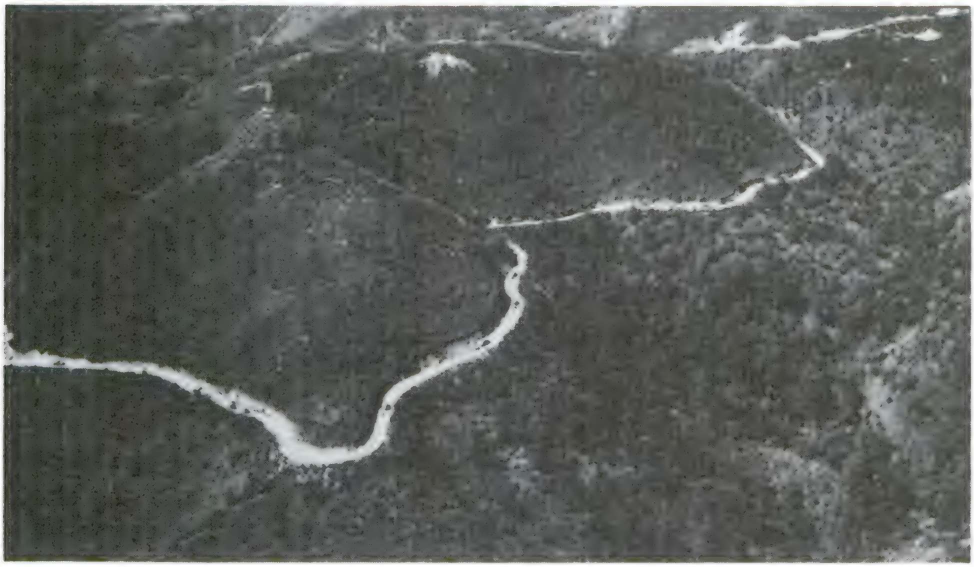
Combat Battalion, the 1905th Engineer Aviation Battalion, and the Chinese 12th Independent Engineer Regiment. By December, Pick had two more units, the 76th Engineer Ponton Company and the 236th Engineer Combat Battalion. In the meantime, he had gained an assistant, Lieutenant Colonel William J. Green, well known to sports enthusiasts as the blocking back for Red Grange at the University of Illinois in the early 1920s.

In the middle of November, the roadhead connected with an advanced section about 40 miles from Shingbwiyang, and by the end of the month had moved another 20 miles. Without the rain and the mud of the monsoon, the engineers found they could move the road about a mile a day. The good weather, new units and equipment, an around-the-clock schedule, and Pick's driving force combined to move the road along rapidly.

On 27 December 1943, five days ahead of schedule, the road reached Shingbwiyang. Finished grading and graveling remained to be done, but the 117 miles from Ledo to Shingbwiyang were open before 1 January 1944, as General Stilwell wished. Pick's celebration for the engineers omitted none of the available essentials. As he congratulated them for opening 54 miles of trace in 57 days, a convoy came rolling into Shingbwiyang with candy, doughnuts, and 9,600 cans of beer.

After reaching Shingbwiyang, the engineers' progress declined due to the tactical situation in the Hukawng Valley. In October, the Chinese 38th Division began an operation to clear the northern part of the valley, but it encountered strong opposition from the Japanese 18th Division. In late December, Stilwell assumed command of the Allied force, which now included the Chinese 22d Division. However, it was not until the first week of February that the Chinese could force the Japanese to withdraw south of the Tanai River.

With the northern Hukawng Valley cleared of Japanese, the engineers could get back to pushing the roadhead. Newly arrived units aided the drive to build as much road as possible before the monsoon arrived. In early January, the 77th Light Ponton Company joined Pick's forces, followed in February by the 71st Light Ponton Company, and the 497th Engineer Heavy Shop Company. The 497th was a unique



The Ledo Road twists its way through the Burma mountains.

organization, as many of its men came from a tractor manufacturing firm in Peoria, Illinois. Lacking cement, they fixed their heavy machine tools to wooden blocks carved from the surrounding jungle and earned a reputation for rebuilding worn parts from salvaged bulldozers and trucks.

In late January, better engineer equipment began to arrive at Ledo as a result of an October 1943 visit by Lieutenant General, and career Army engineer, Brehon B. Somervell, Chief of the Army Service Forces. During his visit, the engineers told Somervell that the D-4 tractor and the 1/2-yard shovel were too small. They asked that the table of organization and equipment for a general service regiment be changed to provide machinery of greater earth-moving capacity. Somervell agreed.

As the new equipment arrived, Pick had the opportunity to exploit fully his method of road building. With Chinese engineers out in front clearing a trace, an American engineer company followed, bulldozing the roadhead. Next an aviation battalion cleared the right-of-way to a width of at least 100 feet. Companies from a general service regiment or an aviation battalion graded sections of 10 to 15 miles and were responsible, with Chinese engineers, for installing culverts. Working with the grading units, an engineer construction or combat battalion built whatever types of bridges were necessary to span the many streams and rivers along the road

route. Finally, an aviation battalion moved in to spread gravel for the final road surfacing.

Pick no sooner got his system into high gear than the tactical situation intervened to divert significant engineer assets away from the road. In February, General Stilwell began his drive for Myitkyina, the main Japanese supply base in northern Burma that sat astride the planned route of the Ledo Road. Its seizure was the main objective of the North Burma campaign.

Stilwell planned to rely heavily in the campaign upon his U.S. Army engineers and a new infantry unit, the 5307th Provisional Composite Unit, code named GALAHAD. The correspondents referred to the latter unit as "Merrill's Marauders," after its commander, now Brigadier General Frank D. Merrill. The Marauders arrived in early February, and Stilwell sent them through the mountains to Walawbum in the southern Hukawng Valley. At the same time, he sent the Chinese 22d and 38th Divisions, supported by the Chinese 1st Provisional Tank Group under U.S. Army Colonel Rothwell H. Brown, down the valley toward Walawbum. The force in the valley needed considerable engineer support.

Stilwell wanted his valley force to use an old ox cart trail, so he directed Pick to turn it into a combat trail. Lying below the flood level, the trail had been rejected as a possible road route. Now Pick had to put his engineers to work on both the trail and the road. In early February he put the 1st Battalion, 330th Engineers, and Company A, 1883d Aviation Battalion, together with several light ponton companies, to work on the combat trail. The 76th pontoniers put a 470-foot pneumatic ponton bridge across the Tarung River and the 71st and 77th Companies built a ponton bridge of similar length across the Tanai River. To provide for aerial resupply, engineers from the 330th Regiment built a dry-weather airstrip nearby, despite the interference of Japanese artillery.

In early March, as the Marauders set a roadblock south of Walawbum, tanks and infantry attacked from the north. A detachment from the 330th, under the command of Lieutenant Albert J. Harvey, supported Colonel Brown's tanks. Harvey's force, using D-7s specially armored by the regiment's mechanics, bulldozed a path through the jungle allowing Brown's Chinese tankers to support the infantry attack

on Walawbum. It fell on 9 March as General Tanaka withdrew the 18th Division south of the Jambu Bum into the Mogaung Valley. The Hukawng Valley was open to the engineers.

As Stilwell continued his drive south into the Mogaung Valley, Pick pushed the engineers to finish as much road as possible before the monsoon arrived in May. Pick's promotion to brigadier general in February brought with it a small, single-engine airplane which enabled him to get about the road more rapidly. He also began to carry a walking stick carved from a giant jungle vine, a practice translated by the engineers into the descriptive phrase, "Pick, the man with the stick."

Pushing the roadhead, Pick rotated units to keep fresh engineers up front. Through most of March, the 45th Regiment led the way, but the 1883d Aviation Battalion moved to the point near the end of the month. After the 1905th Aviation Battalion took over in April, Company A, 330th Engineers, jumped ahead to clear a 4-mile section.

The Hukawng Valley was full of streams and rivers that required substantial bridging. In early April, Company A, 209th Engineer Combat Battalion, with the help of the 76th Light Ponton Company, built a 960-foot H-20 fixed bridge over the Tarung River while the other companies of the 209th bridged the lesser streams beyond the river. By May, Company F, 330th Engineers, had completed a 607-foot H-20 over the Tanai River.

Use of the H-20 bridge on the Ledo Road was a point of controversy with the Office of the Chief of Engineers. In January 1944, the Chief of Engineers sent a team of bridging experts to the CBI to consult with the Ledo engineers about the best bridges to use on the road. They recommended a new British-designed structure, the Bailey bridge, which was replacing the H-20 on U.S. Army authorized equipment lists. The Bailey, erected to spans of 30 to 220 feet, could be built to carry loads from 10 to 100 tons. Since the Ledo Road was being built far behind the front lines, a commercial structure —the I-beam bridge—was also suggested by the team. However, Pick opted for the H-20, arguing that the Bailey required more cargo space than the H-20 and that the I-beam could not be carried by the railway cars of India. The Chief of

Engineers accepted Pick's position and kept the H-20s coming to the Ledo Road. The only Baileys Pick used were those he got from the British in India.

The engineer successes of the dry season stretched well into May, but then came to a halt under the impact of two significant events, one predictable and the other unforeseen. The 1944 monsoon, the predictable event, rapidly gave evidence that it would be as strong as the 1943 variety. Pick decided to concentrate during the monsoon season on maintaining the road rather than suffer the frustrations of trying to forge ahead against the rain, mud, and floods.

The unforeseen event came about in late May when General Stilwell's campaign developed a need for combat engineers. Wanting to seize Myitkyina before the monsoon arrived, Stilwell sent the Chinese 22d and 38th Divisions south in the Mogaung Valley against the towns of Kamaing and Mogaung, while dispatching the Marauders and regiments from the Chinese 30th and 50th Divisions southeast across the Kumon Mountains toward Myitkyina.

As the Chinese in the Mogaung Valley pushed south against stubborn Japanese resistance, the Marauders slipped through the mountains. On 17 May they seized the airstrip on the western outskirts of Myitkyina and reached the edge of town. Company A, 879th Airborne Engineer Aviation Battalion, arrived via glider and had the airstrip ready for cargo planes that night. On 19 May, a detachment of the 504th Engineer Light Ponton Company flew in from Ledo to operate a ferry system over the Irrawaddy River southwest of Myitkyina.

Until the Chinese could seize Mogaung, Stilwell's force at Myitkyina was dependent on aerial resupply. The Japanese 56th Division on the Salween River front and the 18th Division in the Mogaung Valley had land routes to Myitkyina and could reinforce their units there more rapidly than Stilwell. By 23 May, the Japanese were strong enough to push Stilwell's force back from the edge of town and to threaten the airstrip. Needing more infantry and wanting to increase the "American flavor" in the battle, Stilwell sent in the only American combat units available, the 209th and 236th Engineer Combat Battalions.

The 209th Engineers arrived at Myitkyina on 24 May and the 236th got there by the 28th. Both units came directly from the road, and at first they were a bit rusty on the fine points of infantry combat. Catching on quickly, the 209th joined the Marauders in a 31 May operation to draw a ring around the Japanese defense system. Gaining its objective—a hamlet north of town—by 1900, the 209th then held off repeated Japanese counterattacks throughout the night.

In early June, the two battalions were formed into a provisional regiment and brigaded with the Marauders on the northern approaches to Myitkyina. The engineers attacked southward on 9 June and by the 13th were at the edge of the town. A Japanese counterattack then cut off two companies. When an initial relief effort the following day proved unsuccessful and the relief force commander was killed, engineer Captain John C. Mattina assumed command, rallied the relief force, collected the wounded, and led a withdrawal to friendly lines. After another relief effort failed, the surrounded companies successfully withdrew through the Japanese to friendly lines on 16 June.

Engineers of the 1880th Engineer Aviation Battalion scrape the thick layer of mud caused by two days of rain from a temporary bridge near Myitkyina, Burma.

Repeated attacks by Stilwell's force failed to dent the Japanese defenses. When Mogaung fell on 27 June, a land route was finally open from the valley to Myitkyina and

reinforcements gradually produced a force capable of taking the town. A general offensive began on 16 July, and by the 21st the engineers were in the northwest outskirts of Myitkyina. The Japanese began to withdraw on 23 July, and with the issue no longer in doubt, the 209th and 236th Engineer Combat Battalions left for Ledo and a period of rest and recuperation.

The engineers took heavy casualties in the two-month campaign which ended on 3 August with the fall of Myitkyina. The 209th had 71 killed and 179 wounded while the 236th had 56 killed and 112 wounded. All engineer units involved in the fight at Myitkyina received the Presidential Unit Citation.

While the combat engineers were engaged at Myitkyina during the 1944 monsoon, other engineers were busy maintaining the road. As expected, the combat trail in the Hukawng Valley was soon under water and the ponton companies had to operate ferries over the numerous streams and rivers.

Keeping the road open during the 1944 monsoon required the engineers to fight what they called the "Battle of the Bridges." The first bridges to go were those over the Tarung River on 2 May. The 75th pontoniers repaired the permanent bridge while the 76th worked on the ponton bridge. In late May, the 330th Engineers built cofferdams for the Tawang and Tanai bridges as Colonel Hicks, the 330th's commander, prepared to repair expected damage caused by drifting limbs, stumps, and even whole trees. On 8 June, the surging river wrecked the Lamung River timber bridge, and Companies D and F, 330th Engineers, began a reconstruction effort immediately. In late June, the Tawang River bridge began to sag, and Companies D and F added it to their rebuilding work load. When the Numpyek River bridge gave way in early August, the 1883d Engineer Aviation Battalion happened to be working nearby. It got the rebuilding job.

Another major effort during the monsoon season was the construction of a 2-mile timber causeway required by the overflow of the Magwitang River across the road in late June. Pick brought in a drag line and a pile-driving rig and set Company E, 330th Engineers, to work on the 4th of July. Using pilings hacked out of the surrounding jungle, and

aided by two platoons from the 75th pontoniers, the company worked day and night to complete the causeway by 10 August. It stood 18 inches higher than the maximum flood level in the area.

Once the monsoon was over, Pick was ready to push the road south and east from Warazup to link up with the old Burma Road beyond Bhamo. While the Chinese 10th Engineers cleared the jungle, the 330th followed, bulldozing a trace. Behind them the 1880th Engineer Aviation Battalion did finished grading and metaling, and the 1883d and 1905th Engineer Aviation Battalions brought up the rear, performing maintenance and improvement. On 10 October, the 1304th Engineer Aviation Battalion began constructing a 560-foot Bailey bridge over the Mogaung River as the engineers pushed south out of the valley. In November, the 1875th Engineer Aviation Battalion was given the honor of linking

Construction of a Bailey bridge over the Mogaung River south of Warazup, Burma.

the Ledo Road with the road to Bhamo, a prewar, dry-weather track that ran south to the old Burma Road and needed only improvement to meet the all-weather specifications of the Ledo Road.

In mid-October, the Chinese 30th and 38th Divisions, together with the American 47th Infantry and 124th Cavalry Regiments, had begun the drive to Bhamo. It fell to the

38th Division on 15 December. The 30th Division continued the attack up the Shweli River Valley to make contact with a Chinese force that was pushing down the Burma Road from Yunnan Province.

Following close behind the attacking force were the 209th and 236th Engineers, fresh from their recuperation period after the fight at Myitkyina. While they quickly improved the Bhamo Road, the 75th Light Ponton Company built a 1,200-foot ponton bridge over the Irrawaddy River. Completed on 6 December, this 25-ton capacity bridge was at the time the third longest U.S. Army engineer structure, behind only the Union Army James River bridge of 1864 and the Third U.S. Army bridge over the Rhine in 1919.

Christmas 1944, the third on the road for the engineers, was a busy time with the Chinese and American forces pushing the attack to link up with the Chinese from Yunnan and the engineers following close behind, upgrading the final stretches of the road. However, for the men of the 1875th Engineers and the 124th Cavalry there was a brief respite. As the 124th passed through the 1875th camp, the engineers thought the cavalrymen looked as if they needed cheering up. They invited them into their camp to share the festivities of the day. Candy and cake, packages from home, PX supplies and the battalion's beer ration all combined to make it a memorable event. Then it was back to the war.

In January 1945, the 209th and 236th Battalions moved to complete the last sections of the road. When the Chinese 38th Division cleared Mongyu on 27 January, Company B, 236th Engineers, rushed in to complete the junction of the Ledo and Burma roads. That same day the 71st Light Ponton Company put a 450-foot ponton bridge over the Shweli River at Wanting on the Chinese border. The road was open.

It was none too soon for General Pick who, on 12 January, had led the first convoy out of Ledo, bound for Kunming, China. The 113 vehicles, driven by representatives of all the engineer units that had worked on the road, consisted of heavy cargo trucks, jeeps, and ambulances. Among the passengers were some 65 radio, magazine, and newspaper correspondents. The convoy reached Myitkyina on 15 January, where it stayed until 23 January because of the tactical situation. On 28 January, Pick led the convoy into Wanting where

T.V. Soong, the Chinese Minister of Foreign Affairs, welcomed him. On 4 February, the convoy reached Kunming as firecrackers exploded, missionary nuns waved, and Chinese bands played. That night the governor of Yunnan Province gave a banquet with American operatic star Lily Pons and her husband, conductor Andre Kostelanetz, in attendance. Pick's congratulatory message to his command expressed his sincere appreciation and pride in their achievement.

By February, peace had set in along the road as the engineers improved the roadbed and emplaced permanent bridges. That month the civil government of Assam, India, established a customs house at the India–Burma border and a British staff officer from Delhi came to enter into the reverse lend–lease books the number of trees cut from the jungle. The 1905th Engineers had the opportunity to help Father James Devine, newly released from a Japanese prison camp, rebuild his St. Columba's Roman Catholic Mission in the hills east of Bhamo.

A 450-foot Bailey cable bridge supports a convoy en route to China crossing the Shweli River on the Ledo Road.

In March, Company B, 209th Engineers, completed a 450-foot Bailey suspension bridge over the Shweli River at Namhkam. They dedicated it to the engineers lost in the fight at Myitkyina.

Finally, on 20 May 1945, newly promoted Major General Pick announced formal completion of the Ledo Road, a task he called the toughest job ever given to U.S. Army engineers in wartime. Renamed the Stilwell Road at the suggestion of Chiang Kai-shek, it was known to the engineers who built it as "Pick's Pike."

Sources for Further Reading

For the campaign, see the three volumes by Charles F. Romanus and Riley Sunderland, *Stilwell's Mission to China*, *Stilwell's Command Problems*, and *Time Runs Out in CBI*, United States Army in World War II.

The basic engineer story is found in Karl C. Dod, *The Corps of Engineers: The War Against Japan*, United States Army in World War II.

The individual engineer story is available in Leslie Anders, *The Ledo Road*.

SECTION VI

Combat Engineering: War in the Far East

For the United States, World War II began in the Pacific. By December 1941, the war in Europe was already more than two years old, but in the Far East it was more than four years old. The Japanese attack on Pearl Harbor and conquest of the Philippines were new stages in Japanese expansion, which had led to the outbreak of war with China in July 1937. As British, French, and Dutch colonies in Southeast Asia and the South Pacific fell before the onslaught of the Japanese, the newly allied western powers improvised desperately to preserve what they could of their prewar empires.

The basic outline of the Allied wartime strategy in the Far East was easily arranged, partly due to necessity. Already under heavy pressure from the Germans in Europe, the British confined their efforts to protecting India and Burma. The rest of Southeast Asia and the Pacific became the United States' responsibility with Australia and New Zealand playing important roles. Although the Allies agreed early that the European theater should have priority, the Pacific theater required a heavy commitment of America's scarce military resources. Dislodging the Japanese from the empire they conquered quickly in late 1941 and early 1942 turned out to be a difficult and costly task.

Early in 1942, while the Japanese were still advancing, the Joint Chiefs of Staff established the basic command arrangements that would persist throughout the war. Geography dictated that the Navy and air power would predominate in the Pacific war, but General Douglas MacArthur's stature and the necessity for cooperation between the Army and Navy resulted in two Pacific theaters: the Southwest Pacific Area (SWPA) under MacArthur, and the Pacific Ocean Area (POA), which covered the bulk of the ocean, under Admiral Chester Nimitz.

Both theaters required an enormous engineer effort. Most of the Pacific islands lacked even rudimentary modern facilities, and climate and terrain conspired to make the construction of even basic facilities difficult. The American strategy, however, called for an abundance of facilities such as airfields, ports, huge logistical depots, and roads. Fighting weather; terrain; shortages of equipment, supplies, and troops; and also the enemy, the engineers labored to provide the modern military infrastructure that the island-hopping Pacific campaigns demanded. The engineer effort was so important that General MacArthur referred to the war in his theater as an "engineer's war."

In the Southwest Pacific, American engineers arrived in the theater early and began work quickly. The first American troops on the strategically important island of New Guinea were engineers. When MacArthur decided to defend Australia by blocking the Japanese advance in New Guinea, he launched a two-year campaign to defeat or bypass the enemy troops holding the island. New engineer missions and new types of engineer units were tested during this arduous campaign. Specially equipped and trained aviation engineers built dozens of airfields to support the new air warfare, which played a critically important role in the Allied victory in the Pacific. To assist in the many amphibious landings that geography and strategy dictated, the Army fielded new and unusual engineer amphibian units. All military operations in SWPA eventually culminated in the reconquest of the Philippine island of Luzon, the largest American land campaign in the Pacific. From the landings on Lingayen Gulf through the rapid advance across the island to the bitter street fighting in Manila, the engineers made a major contribution to the American victory in SWPA.

While most of the war in the Far East was fought in the warm tropical waters of the Central and South Pacific, American forces also engaged the Japanese on the edges of the frigid Bering Sea. As part of the campaign that culminated in the Battle of Midway, the Japanese seized and held two remote Aleutian islands in 1942. Reconquering the islands was a difficult and bitterly fought operation in which engineers made important contributions, including fighting as infantry.

Further south in Nimitz's theater, where the Navy and Marines provided the bulk of the forces, the Army and its engineers played a smaller role. But the Army component command of POA and its engineers, drawn heavily from the prewar Honolulu Engineer District, constructed facilities throughout the theater and fought in ferocious battles like the one on Okinawa. As American and Allied forces got nearer to the home islands, Japanese resistance became more desperate, leading American planners to anticipate a bloody invasion. But the impact of fire bombing and the two atomic bombs forced the Japanese government to surrender in August 1945.

The essays that follow touch briefly on a few of the engineer activities that contributed to American victory in the Far East. The first essay describes the activities of aviation and amphibian engineers in MacArthur's difficult, two-year campaign to take New Guinea and surrounding islands as a springboard for his return to the Philippines. Leaving the tropical South Pacific, the second essay surveys the little-known campaign to wrest the Aleutian island of Attu from its Japanese conquerors. During the last year of the war, American troops fought the two largest battles in the Pacific on the islands of Luzon and Okinawa, and two essays discuss these important campaigns. American forces and engineers fought and built in many other Far Eastern locales, but these essays give some idea of the range and nature of the engineer contribution in the Pacific.

Aviation and Amphibian Engineers in the Southwest Pacific

by William C. Baldwin

In 1944, General Douglas MacArthur told the Chief of Engineers, who was touring the general's Southwest Pacific theater, "this is an air and amphibious war; because of the nature of air and amphibious operations, it is distinctly an engineer's war." From the beginning of the war in the Pacific, engineers played a critical role in stopping Japan's stunning offensive into the South Pacific toward Australia and then slowly and painfully pushing the tenacious Japanese forces back across the island of New Guinea and into the Philippines. By October 1944, on the eve of the landings on Leyte, 100,000 of the 700,000 troops in the Southwest Pacific were engineers. The strategic and tactical problems encountered in the more than two years of fighting on New Guinea not only dictated a large role for engineers, but also demonstrated the value of two new, specialized types of engineer units, which responded admirably to the demands of MacArthur's air and amphibious war.

In 1939, the War Department asked the Corps of Engineers to submit plans for organizing engineer construction units to support the Army Air Corps. The Chief of Engineers proposed the formation of engineer aviation regiments and, in June 1940, made the 21st Engineer Regiment the first experimental aviation unit, the parent unit for aviation engineers who, at their peak in early 1945, would number almost 120,000 officers and men.

During the early years of the war, the engineer aviation battalion (EAB) of 27 officers and 761 enlisted men became the standard and most common aviation unit. Designed to be able to build an airfield independently in a reasonable period of time, the aviation battalion contained more and heavier construction equipment than other engineer battalions and was staffed to permit two and three shift operations. By December 1941, the hurriedly trained 12 new battalions

of aviation engineers were scattered from the Philippines and Hawaii to Alaska and the Caribbean.

After the German army rapidly overran France in 1940, the War Department also began to think more seriously about amphibious warfare and the probability of a cross-channel invasion to liberate the European continent. Although traditionally a Navy and Marine Corps mission, extensive amphibious operations in both the Atlantic and the Pacific would require heavy Army participation. In early 1942, the War Department, with the reluctant agreement of the Navy, inaugurated its own amphibious warfare training program and in June established the Engineer Amphibian Command (EAC) at Camp Edwards, Massachusetts.

Initially the EAC had the task of providing and training the crews of the landing craft which would conduct shore-to-shore operations; but under the aggressive leadership of Brigadier General Daniel Noce and his staff, the EAC soon broadened its mission to include most aspects of Army amphibious warfare, including doctrine, organization, and equipment. After numerous experiments, the EAC developed the engineer amphibian brigade, later renamed the engineer special brigade, as the basic unit. Composed of three engineer boat and shore regiments and supporting units such as boat maintenance, quartermaster, and signal, the special brigade would transport troops, equipment, and supplies in a fleet of small landing craft, land them on enemy beaches, organize the beachheads, and provide them with logistical support.

Ultimately the Army formed six engineer special brigades. Three brigades, operating entirely as shore units, participated in landings in North Africa, Sicily, Italy, and Normandy. The other three, operating as boat and shore units, went to General MacArthur's Southwest Pacific theater and played an important role in most of his operations against the Japanese.

When the Japanese attacked Hawaii and the Philippines in early December 1941, engineer aviation battalions had already arrived in both locations. The 804th EAB immediately began repairing Hickam Field on Oahu, and the 803d exerted valiant efforts in Bataan and on Corregidor before its survivors surrendered to the Japanese.

Diverted from the Philippines after the Japanese attack, the first American reinforcements for the Southwest Pacific arrived in Australia in late December; and by January 1942, the first engineer officers, including Major George T. Derby and Major Elvin R. Heiberg, Jr., began organizing the American construction effort there.

On 2 February 1942, the first engineer troops—the 808th Aviation Battalion under Captain Andrew D. Chafin, Jr.—landed in Melbourne and set off on a trip by truck and rickety rail across the continent to Darwin on the north coast. Activated in September 1941, the battalion had received scant training before its deployment. Operating in complete isolation from the American Army, it began building airfields near Darwin in the combat zone without most of its equipment.

In late February, two engineer general service regiments, the 43d and the 46th, arrived in Melbourne. One battalion of the 43d prepared camps for the arriving American divisions in southern Australia, while the other battalion joined the 808th near Darwin. The 46th moved to the vulnerable northeastern coast and began airfield construction. Trained and equipped for general construction in the communications zone, the general service units had inadequate equipment, and the engineers often labored with hand tools to build the primitive but serviceable airfields as rapidly as possible. One company cleared a site and laid a pierced steel plank runway, 2,500 by 100 feet, in five days.

As the Japanese threat to northern Australia intensified, the need for airfields grew faster than Australian or American engineers could respond. The situation improved somewhat in early April when two separate battalions, the 91st and 96th, arrived. Composed of black troops, the separate battalions were designed primarily to support other units and had little organic equipment. Even with the small engineer reinforcements, the military situation in the Southwest Pacific remained grim in the spring of 1942.

Confronted with the imminent defeat of American and Filipino forces holding Bataan, President Franklin Roosevelt had ordered their commander, General Douglas MacArthur, to leave the Philippines and take charge of defending Australia—the last major Allied outpost in the Southwest Pacific. The Japanese were threatening to sever the lines of

engineers to the island, including two companies of the 43d to Milne Bay.

Meanwhile, in late August, a second Japanese force attacked the Allied troops at Milne Bay. Companies D and F of the 43d Engineer General Service Regiment along with an American antiaircraft battery joined the Australians in holding defensive lines on the edge of an airfield and became the first American ground troops in SWPA to engage in combat. The Allies defeated the Japanese at Milne Bay, and by late September the Australians began pushing the Japanese back over the Kokoda Trail. SWPA had stopped the Japanese attempt to conquer Port Moresby, but it would take two more years of bitter and bloody fighting to defeat or isolate the large Japanese forces that held the northern coast of the island.

By November 1942, Australian troops and the American 32d Infantry Division were converging on the Japanese strongholds at Buna. Engineers, using only hand tools at first, built airstrips at Dobodura, just south of Buna, to support the Allied attack and eventually developed the Dobodura–Oro Bay area into a major base. Taking advantage of the swamps and jungle around their strongholds, the Japanese built coconut log bunkers and other well concealed and well sited positions. Largely untrained and poorly equipped for jungle warfare, the Allies suffered heavy losses from both combat and disease before Buna fell in early January 1943. The Allied victories at Buna and at Guadalcanal in the South Pacific Area represented the first decisive defeats of the Japanese ground forces in World War II.

During the first six months of 1943, neither SWPA nor the South Pacific Area launched any offensives. Because the European theater had first priority, few troops or supplies arrived in the Southern Pacific. No new engineer units reached SWPA from June 1942 until February 1943. As the theater rebuilt its strength after the heavy demands of the Buna campaign, the Pacific commanders and the Joint Chiefs of Staff agreed on a campaign plan for late 1943. MacArthur would continue his drive up the northern coast of New Guinea, and South Pacific forces would attack Bougainville in the Solomons. These operations would put pressure on the great Japanese base at Rabaul on the eastern end of New Britain Island. In 1943 and early 1944, the Pacific theater forces would gradually isolate and then bypass Rabaul.

In late June 1943, the Allies seized islands just east of New Guinea and built airfields which allowed Allied air forces to launch heavy air attacks on Rabaul. At the same time, SWPA began a series of operations designed to capture the next Japanese bases up the coast of New Guinea—Salamaua and Lae. Amphibian engineers carried out their first operation in SWPA during this campaign.

General MacArthur had requested amphibian engineers for his theater at an early date because of the Navy's reluctance to risk its ships in the dangerous and confined waters off the New Guinea coast and because the combination of boat and shore units under engineer control solved the knotty problem of whether the Army or the Navy would be in charge of amphibious operations in SWPA. Under the command of Brigadier General William F. Heavey, the 2d Engineer Special Brigade arrived in Australia in February and March 1943. Its first task was to assemble landing craft shipped from the United States.

During the early stages of planning the deployment of amphibian engineers to SWPA, Colonel Arthur Trudeau, chief of staff of the EAC, discovered that it would take months to ship the brigade's landing craft to the theater. Trudeau devised a plan that called for prefabricating the 36-foot LCVPs (landing craft, vehicle and personnel) in more easily shipped sections and assembling the boats in Australia. The 2d Brigade built an assembly plant in Cairns and began producing its own landing craft.

In late June, the amphibian engineers participated in their first SWPA operation. During the night, landing craft of the 532d Engineer Boat and Shore Regiment transported a small force through heavy seas to a landing beach at Nassau Bay, just south of the Japanese base at Salamaua. Although the troops landed safely, most of the landing craft were swamped by the heavy surf. In addition to unloading equipment and supplies, the shore engineers helped to establish and man defensive positions, which the Japanese attacked the next night. The 532d lost an officer and six men who were killed and another eight who were wounded in repelling the Japanese assault.

As part of the developing Allied assault on Lae and Salamaua, General MacArthur ordered aviation engineers

After rolling and compacting an airstrip in the Markham Valley, New Guinea, aviation engineers place pierced steel plank on the 7,000-foot runway.

to build airfields in the isolated Markham River valley, just to the west of the Japanese strongholds. In early July, a company of the 871st Engineer Airborne Aviation Battalion under the command of Lieutenant Colonel Harry G. Woodbury, Jr., began work on a fighter and a transport field. The small airborne battalion of 530 officers and men had equipment which could be transported in C-47s or gliders. By the end of the month, the battalion with the assistance of native laborers had completed the fields. Australian and American forces, including aviation and amphibian engineers, continued to exert pressure on the Japanese bases, which finally fell in early September 1943.

Before the Japanese could recover from these losses, MacArthur ordered an attack on Finschhafen, another Japanese base east of Lae. In late September 1943, the 2d Engineer Special Brigade landed Australian troops near the village, which fell on 2 October. Strong Japanese forces remained in the area, however, and threatened the tenuous Allied beachhead. A detachment of the brigade's 532d Boat and Shore Regiment remained on the beach to help the Australians defend it from seaborne counterattack.

As dawn approached on 17 October, the defenders heard the faint sound of boats gliding toward the beach. Private

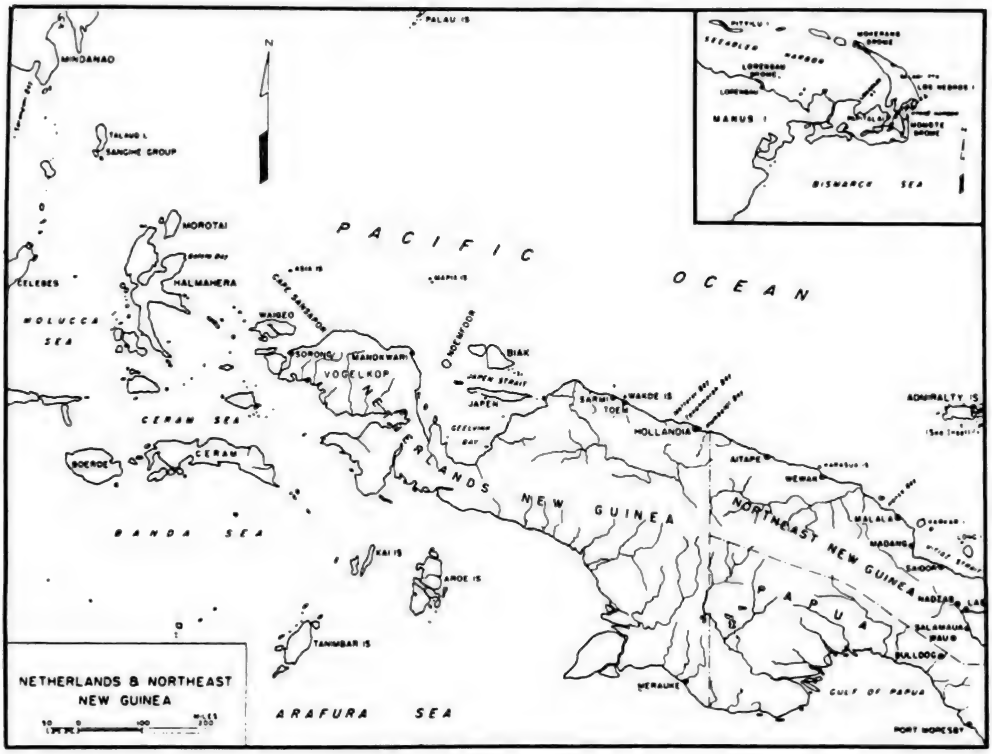
Nathan Van Noy, Jr., and Corporal Stephen Popa rushed to their .50-caliber machine gun position just a few yards from the water line. Slowly the silhouettes of Japanese landing barges came into view. The Australians and American engineers farther up the beach opened fire, but Van Noy, the gunner, waited until the barges dropped their ramps. As the Japanese stormed onto the beach, Van Noy opened fire, killing many of the invaders. A hail of Japanese grenades shattered Van Noy's leg and wounded Popa. In spite of their wounds, the two engineers continued to fire.

After the Allied troops had repulsed the Japanese raid, they found Van Noy dead, his finger still on the trigger of his empty machine gun, and Popa severely wounded. Popa received a Silver Star and Private Nathan "Junior" Van Noy became the first engineer enlisted man in World War II to receive the Medal of Honor.

During 1943, the strength of the U.S. Army and Army engineers in the Southwest Pacific theater grew dramatically. At the beginning of the year, the 7,500 engineers comprised 7 percent of the Army forces, but by the end of the year the more than 42,000 engineers comprised 14 percent of the SWPA Army strength. Headquarters, Sixth Army, under Lieutenant General Walter Krueger had arrived in SWPA in February 1943 but did not take control of major operations until the end of the year. The Engineer Section, Sixth Army, was under Brigadier General Samuel D. Sturgis, Jr., who was Chief of Engineers from 1953 to 1956. Sixth Army provided the troops for the task forces that conducted most of the remaining operations in New Guinea. Each task force had an engineer who was responsible not only for combat support, but also for the initial phases of base development and airfield construction, which often began before combat operations had ceased.

In late December and early January, American troops under the control of the Sixth Army continued their pressure on the important Japanese stronghold at Rabaul by landing on western New Britain Island and at Saidor on the New Guinea coast. Amphibian engineers supported the landings on New Britain using newly developed rocket DUKWs, which were 2 1/2-ton amphibian trucks equipped with 120 rocket tubes. As soon as the American troops had cleared the

areas, 6 engineer aviation battalions, including the 808th, began building airfields. By January 1944 MacArthur had 17 engineer aviation battalions and 3 airborne aviation battalions in the theater.



Netherlands and Northeast New Guinea

In order to complete the isolation of Rabaul and provide bases for the advance in New Guinea, MacArthur ordered an American task force to capture the Admiralty Islands, north of the New Guinea coast. Supported by amphibian engineers, American troops quickly seized the islands, and aviation engineers began building airfields. With the Admiralties under American control, the JCS and MacArthur decided to speed the advance along the New Guinea coast by avoiding a direct assault on large Japanese troop concentrations at Hansa Bay and Wewak and instead attacking the lightly held Hollandia area some 200 miles west of Wewak. On 22 April 1944, the 532d and 542d Boat and Shore Regiments of the 2d Engineer Special Brigade landed the largest task force assembled thus far in SWPA on two beaches separated by 25 miles of rugged coastline. Of the

Engineer LCVPs and LCMs load into the well deck of a landing ship, dock, just before the Hollandia landings, 22 April 1944.

60,000 troops who participated in the landing, 41 percent were engineers. Initial plans called for developing the Hollandia area into a major American base, and four aviation battalions under the command of Headquarters, 931st Engineer Aviation Regiment, began rebuilding three inadequate Japanese

Landing craft of the 2d Engineer Special Brigade head toward the beach during the Hollandia operation. The prominently displayed American flags helped Army Air Force pilots identify the craft as friendly forces.

airfields. In spite of the efforts of the aviation engineers, which included surfacing one field with a combination of sand and iron ore from a nearby deposit, the difficult terrain precluded the construction of airfields for heavy bombers and prevented Hollandia from becoming as large a base as SWPA had envisioned.

The need for bomber fields led MacArthur to move up the schedule for the next landings on the western New Guinea coast. In mid-May, the 593d Engineer Boat and Shore Regiment of the newly committed 3d Engineer Special Brigade landed a task force on Wakde Island, 125 miles west of Hollandia. Although the Japanese offered surprisingly heavy opposition on Wakde, the 836th Engineer Aviation Battalion had an airfield ready to support the next operation by 21 May.

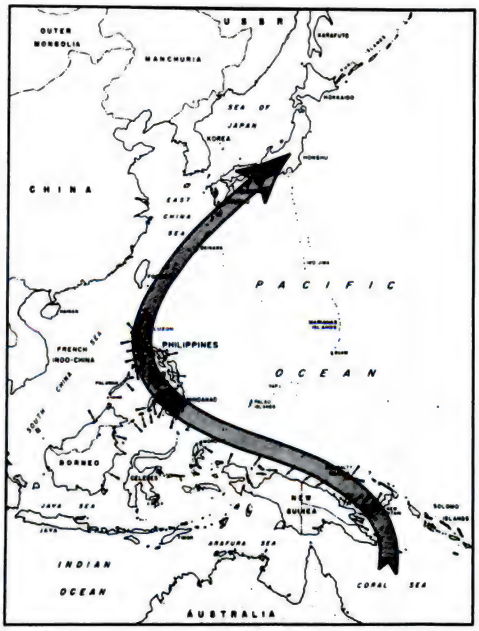
Supported by amphibian engineers, the landings on Biak Island, 75 miles to the west, on 27 May encountered little resistance; but when the task force began moving toward the airfields, it ran into heavy fire from Japanese defenses in caves along the coral cliffs. With airfield construction at a standstill and rumors of Japanese plans to reinforce Biak, the task force commander ordered aviation engineers to build an airfield on the small island of Owi, just south of Biak. In less than two weeks, the Owi field was operational; and shortly thereafter the task force, using a flanking movement along the top of the cliffs, cleared the Biak fields, which the engineers quickly improved for both fighters and bombers. The fighting on Wakde and Biak was heavy because the Japanese garrisons were composed of seasoned combat troops.

In July 1944, SWPA forces seized two more areas in western New Guinea to bring the airfields closer to the Philippines. On 2 July, a task force landed with little opposition on Noemfoor Island, 90 miles west of Biak, and built airfields and a small base. On 30 July 1944, SWPA made its last landing in New Guinea at Cape Sansapor on the Vogelkop peninsula. Aviation engineers built a bomber base on the coast and, using coral dredged from the ocean, constructed a fighter strip that extended virtually the entire length of tiny Middelburg Island just offshore. Cape Sansapor, however, was still 600 miles from Mindanao in the Philippines. Before MacArthur returned to the Philippines, his forces, now including the 4th Engineer Special Brigade,

Aviation engineers construct an airfield stretching the entire length of Middelburg Island, September 1944.

captured an intermediate base at Morotai Island in the Moluccas in September. By this time, the last airfields in New Guinea were in operation and the long New Guinea campaign was over. MacArthur was now in a position to redeem his pledge, made more than 2 1/2 years earlier, to return to the Philippines.

From the arrival of the first American ground troops, who were engineers, until the final landing in July 1944, engineers played a critical role in New Guinea. General MacArthur acknowledged this role in 1944 when he referred to the war in the Southwest Pacific as "an engineer's war." The New Guinea terrain and the bypassing strategy required a large engineer effort in amphibious operations and in airfield and base construction. The number of engineer troops in SWPA indicates the significance of their mission. In January 1943, there were



General MacArthur's strategy 1943–1945

7,500 engineers in SWPA; in January 1944, there were 42,000; and by October 1944 on the eve of Leyte, 100,000 of the 700,000 troops in SWPA were engineers.

The two new types of engineer units played an especially important role in the Southwest Pacific. In the ten major landings conducted from December 1943 to September 1944, amphibian engineers comprised an average of 26 percent of the task forces' engineer strength. In the largest landing in New Guinea—in Hollandia—the 24,600 engineers comprised 41 percent of the total task force strength. More than 4,000 were amphibian engineers and more that 7,500 were aviation engineers. By the summer of 1944, SWPA had 3 engineer special brigades, each with an authorized strength of 7,200 officers and men, 31 engineer aviation battalions, 6 airborne engineer aviation battalions, and 2 engineer aviation regimental headquarters.

On the eve of war, the engineers had responded to the new challenges of amphibious and air warfare by developing new types of engineer units. These units received their most extended test and performed some of their most critical work in the Southwest Pacific. The difficult terrain of New Guinea and MacArthur's strategy for defeating the Japanese gave amphibian and aviation engineers an important role to play. Although many difficult operations lay ahead of them in the Philippines, SWPA engineers, in the summer of 1944, had reason to be proud of their accomplishments in the New Guinea campaign.

Sources for Further Reading

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The Battle of Attu

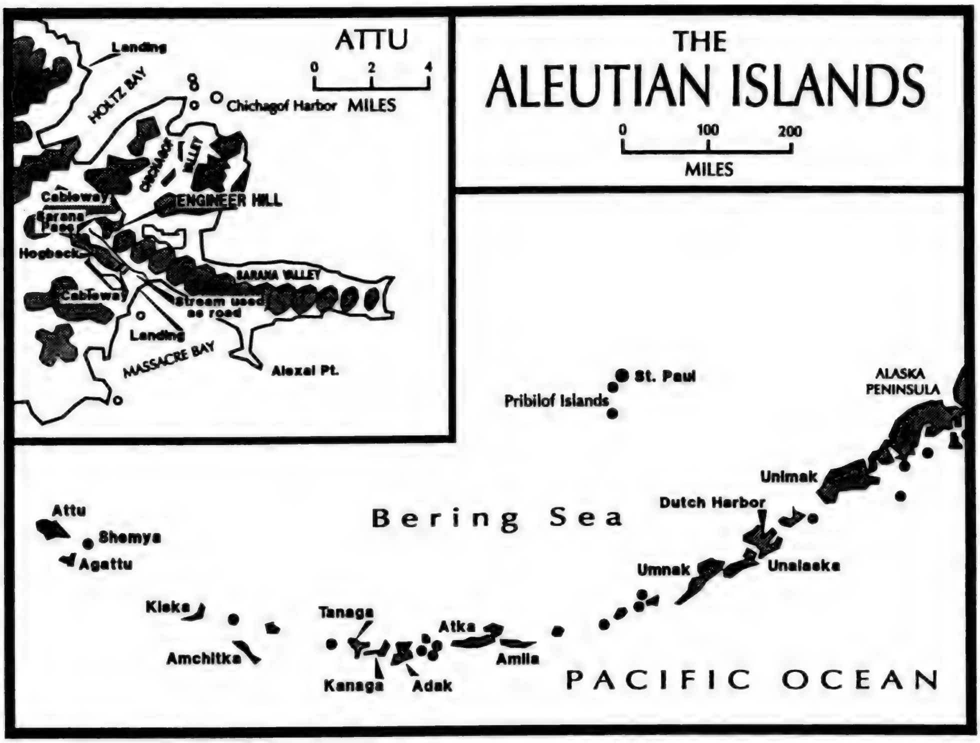
by D. Colt Denfeld

In the May 1943 battle of Attu Island, engineer troops performed both as fighters and as builders. During the battle, Army engineers devised innovative solutions to keep the supply line open to the fighting troops. Engineers also fought, repulsing a major Japanese counterattack and ending organized resistance on the island.

Japan had captured Attu and Kiska islands on 7 June 1942 during the Midway–Aleutians operation. Midway was the main battle, but the sideshow in the Aleutians, including a carrier aircraft raid on Dutch Harbor and the acquisition of two isolated islands in the western Aleutians, gained importance as compensation for the defeat at Midway. These islands blocked any northern approach to the home islands, and the capture of American soil was a political and psychological victory.

The United States responded quickly with bomber attacks. These were ineffective because of antiaircraft defenses and the cruel Aleutian weather. Then came naval bombardment, which also proved futile. The failure of bombardment to dislodge the Japanese lent support to a proposal of Lieutenant General John L. DeWitt, commander of the Western Defense Command, for a land offensive. In the summer and fall of 1942, however, there were more pressing needs. The intermediate response was to advance airfields westward to Adak, 280 miles east of Kiska, and Amchitka, which is only 80 miles distant. From these bases bombers and fighters could exploit short breaks in the weather when clear skies would allow more precise attacks.

The 807th Engineer Battalion (Aviation) landed at Adak on 31 August. The first task facing its commander, Lieutenant Colonel Carlin M. Whitesell, was to find the best airfield site. Mountainous Adak had never been adequately surveyed or mapped but was known to have few suitable airfield locations. Probably the best site was a tidal marshland on Sweeper Cove. This marsh had a firm sand base that was covered



Aleutian Islands and Attu

by water twice daily. If the tide could be drained and controlled, the firm sand would create a solid base for a runway. Lieutenant Colonel L.B. Delong—an assistant to Colonel Benjamin B. Talley, officer in charge of Alaska construction—and Major James D. Bush, of Talley's staff, studied the problem. They designed a dike and canal system with gates on Sweeper Cove to drain the tidal marsh. Once the dike and gates were installed, water was drained off, the topsoil was scraped away, and the base was laid for the runway, which was then covered with a pierced steel mat. The field was ready for the first landing in nine days and combat ready in a few more days. Operations were moved from Umnak to Adak on 13 September.

The Western Defense Command received approval in December 1942 to occupy Amchitka and to plan for an amphibious assault at Kiska. Kiska was near the planned air base on Amchitka and had a better harbor than Attu. Kiska also had problems, including strong coastal defenses and more enemy troops than Attu.

On 17 December, Colonel Talley led a survey party to locate airfield sites on Amchitka. They found test pits indicating that the Japanese had recently been there, and as they were conducting their reconnaissance, a Japanese float plane flew over. The survey party was not seen and returned safely to report on suitable locations in the Constantine Harbor area.

The initial landings at Amchitka came on 12 January. The 813th Engineer Battalion (Aviation) went to work first to build a fighter strip. On 24 January, Japanese aircraft bombed and strafed the engineers, catching them at work. Casualties were light and work went on. By 16 February, the runway was ready for fighters. Eight P-40s and several P-38s landed that day. A bomber runway was begun in early March. This runway would play an important role in the Kiska operation.

By early March, it was clear that shipping for a force large enough to assault Kiska would not be available, so the more lightly defended Attu Island was substituted. Capture of this more western island would cut off supplies to Kiska, leaving it to wither on the vine. The final decision to assault Attu was made on 22 March, with the invasion scheduled for 7 May 1943. Invasion planning was helped along by a naval success on 26 March. In the battle of the Komandorski Islands, Rear Admiral Charles "Soc" McMorris repelled a Japanese force escorting three transports to Attu. Henceforth, the resupply of Attu and Kiska was limited to what could be carried on submarines and the few destroyers that made the trip.

The 7th Infantry Division sailed from San Francisco on 24 April and arrived at Cold Bay on the Alaska Peninsula on 30 April. The final plan for the assault called for the main landing at Massacre Bay (Southern Landing Force) and a Northern Landing Force to land on beaches on the north at Austin Cove and Holtz Bay. The main force was to push up Massacre Valley and seize the passes leading to Holtz and Sarana Bays. The northern force would destroy the main Japanese base in Holtz Bay, then link up with the southern force in the Holtz Bay area and drive the remaining Japanese into a pocket in Chichagof Harbor. The 7th was expected to capture Attu in three days.

The 7th Infantry Division was composed of the 17th and 32d Infantry Regiments, field artillery battalions, the 13th Engineer Battalion (Combat), and medical and other support troops. The 50th Engineer Battalion (Combat) was assigned to the division to effect the landing and movement of supplies inland from the beaches. Major General Albert E. Brown commanded the division. Elements of the 4th Infantry Regiment of the Alaska Defense Command were placed on reserve and positioned at Adak.

Bad weather delayed the departure of the attack force from Cold Bay. The ships steamed along the south side of the Aleutian chain, entered the Bering Sea by Amukt Pass, and to avoid detection steered well north of Kiska to the turn-in point 115 miles northeast of Attu. When the invasion forces finally reached Attu, an island 37 miles long and 15 miles wide, it was invisible in the heavy fog. If they could have seen the island, they would have noted that it was mountainous and covered with tundra—a thick, wet, spongy mat of grass and herbs—at lower elevations. Many of the bays had suitable landing beaches, so the Japanese could not defend them all. The most sheltered harbors were on the eastern end of the island. The Japanese had their camps on this end, and it was here that the 7th would invade.

The first landings were on a small northern beach at Austin Cove, code named Beach Scarlet. The 7th Scout Company, brought to Attu on the submarines *Narwhal* and *Nautilus*, landed there on rubber boats. The scouts walked ashore between 0309 and 0510. They were followed by the 7th Reconnaissance Troop aboard the destroyer *Kane*. Hampered by fog, the *Kane* could not disembark troops until noon on 11 May. Waiting for the Americans were about 2,500 Japanese defenders under command of Colonel Yasuyo Yamasaki. The Japanese encampments were at Holtz Bay, Chichagof Harbor, the ridgelines above Sarana and Massacre bays, and outposts at Scarlet Beach and Stellar Cove.

Both the northern and the southern landings were unopposed. The first Japanese response came in the early evening, when a northern force beach patrol surprised an outpost of four Japanese. Two of them were killed, but the others got away. Within a few minutes the northern force came under fire from 75-mm. guns at Holtz Bay.

American troops in the south met their first opposition soon afterward. Everywhere stubborn resistance halted the advance. The southern force progressed only 4,000 yards in the first 48 hours. The Japanese defenders fought with machine guns as well as with snipers who were hidden in rain washes, holes, and trenches located at various levels on each side of narrow passes leading through the mountains. In addition, small infantry groups were dug in high up on sides of the passes parallel to the axis of approach. It was impossible to approach positions on sides of a pass from the slippery snow-covered slopes above.

Cold injuries plagued soldiers on Attu Island. (U.S. Signal Corps, Alaska State Library)

Not only were the fighting troops stopped, but artillery, ammunition, and supplies piled up on the beaches. Once the division's vehicles and towed guns left the beach, they became mired in the boggy tundra. Cold weather injuries also confronted the troops. Their clothing and boots were not appropriate for the climate and terrain of Attu.

On 13 May, Colonel Talley reviewed the engineer supply situation with the force engineer, Lieutenant Colonel James E. Green, and Lieutenant Colonel Virgil Womeldorff, commanding officer of the 50th Engineer Battalion. Talley asked them their plans for road construction. Green replied that they did not have road construction equipment. Talley

recognized the need for roads to achieve victory and hold the island. On 14 May he asked for engineer equipment and supplies for 60 days for the final neutralization of the Japanese and post-battle construction.

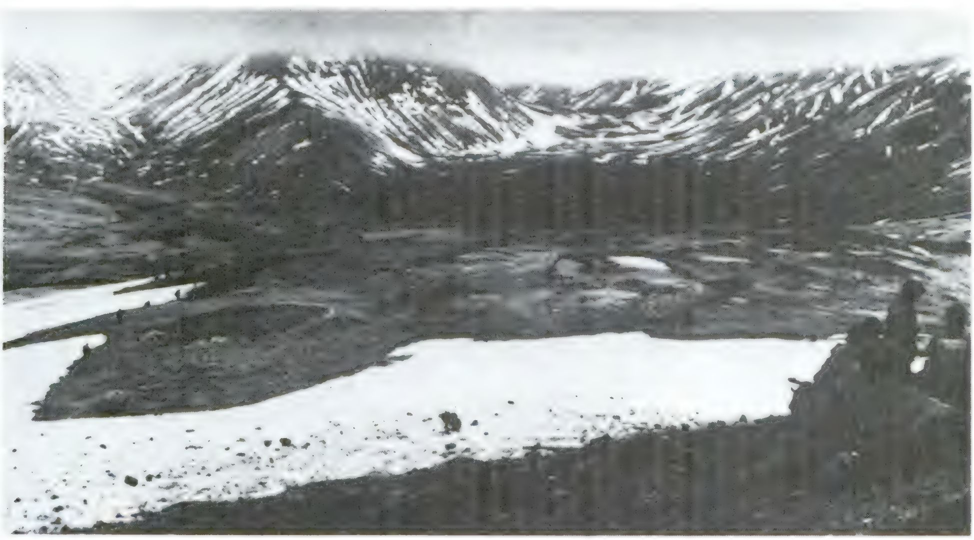
The request was misunderstood to mean that neutralization of the Japanese would take 60 days. How could equipment for 60 days be needed when the original plans called for capture of Attu in three days? In fact, without an enemy before them, the 7th would have done well to have walked the spongy tundra in that length of time. But the fight would not take 60 days either, and now headquarters believed that the 7th Division anticipated a prolonged battle. Rear Admiral Thomas C. Kinkaid, Commander, North Pacific Force, relieved the division commander and appointed Major General Eugene M. Landrum in his place.

Troops struggle to move a gun mired in the Attu Island tundra. (U.S. Signal Corps, Alaska State Library)

Seven companies of engineers had been assigned to the invasion, six of them with the main force at Massacre Bay. These six companies had the primary responsibility of moving the equipment and supplies off the landing beaches. This meant finding an answer to the problem of moving the guns and supplies up from Massacre Valley. There was neither the time nor the heavy equipment to build roads. Realizing that something had to be done in a hurry, the assault force

engineers, Lieutenant Colonel Green and Major Bush, hit upon a solution. They proposed to use a stream that flowed down the east side of the valley as a roadway. The 13th Engineer Battalion (Combat) improved the rocky creek bed by widening and straightening some sections. Within hours, a steady stream of tractors towed supply laden wagons up the valley. The roadway functioned as the main supply route throughout the battle.

From the stream a cableway was constructed up the slope of Hogback. The Hogback itself was a low squat ridge with only 1 to 2 feet of tundra over the bedrock so graders could construct a road by removing the tundra. But the lower slope of the Hogback was another problem. It had a much deeper layer of tundra, so the cableway was constructed from the valley floor halfway up the ridgeline to a point at which the tundra layer was only 1-foot deep. From the end of the ridgeline cableway, on which a tractor with a winch pulled sleds loaded with supplies up the hill, a road was built to the northeast end of Hogback so the troops who pushed north to the final combat zones could be supplied. The north end of Hogback touched a hill at the north end of the eastern ridgeline of Massacre Valley. This hill was captured on 21 May and named Engineer Hill. A road was to be built across Engineer Hill and Sarana Pass to Prendergast Ridge,



Soldiers advance up an Attu valley. *(U.S. Signal Corps, Alaska State Library)*

where American troops were advancing east to trap the defenders. American progress had been slow but steady.

The Sarana Pass section of road would require considerable grading and the removal of 4 to 5 feet of tundra. The fighting troops could not wait for the road, so a temporary cableway across Sarana Pass was necessary. To install the cable, a tractor would be needed at the bottom of Engineer Hill. The tractor would anchor the cableway across the valley to the foot of Prendergast Ridge and winch the supply sleds down the hill.

The 40-percent, 1,000-foot-long tundra slope of Engineer Hill was too steep to be crossed by tractors. After looking over the situation, engineers seized upon a quick but risky solution. They pushed six tractors over the slope to the floor of the valley below, assuming that at least one would land

Supplies pile up on Massacre Bay. Tractors wait on a streambed to be loaded for another trip up an Attu valley. (U.S. Signal Corps, Alaska State Library)

intact. All six survived the tumble. A tractor and cable system was soon in operation across the valley. Supplies were moved forward, and wounded soldiers were taken to the rear on the return trips.

By 28 May, Colonel Yamasaki had his back to the wall. He could stand and die, surrender, or retreat to the hills of

Khlebnikof Point. Surrender was unacceptable, and a suicide stand in Chichagof Harbor would only delay the end a short time. The withdrawal into Khlebnikof would give him a few more days, but his supply situation there would be hopeless. Yamasaki thought of a daring gamble that could return his troops to the offensive. His plan was to capture the high ground and American artillery emplaced behind Engineer Hill. He would turn the artillery against the American supply dumps in Massacre Valley, destroying the depots and disorganizing the American forces. The assault forces could be isolated and attacked.

At 0300 on 29 May, 800 to 1,000 Japanese rushed up Chichagof Valley and through a temporary gap at Lake Cories. They overran two command posts, killing the occupants, including Lieutenant Colonel James Fish. The main counterattack then hit the medical collecting station at the mouth of Chichagof Valley. The patients and staff received no warning. Many were shot or bayoneted in their sleeping bags.

Once the collecting station had been destroyed, the main Japanese force struck Engineer Hill. Lieutenant Colonel Womeldorff of the 50th Engineers had issued extra grenades and ammunition the previous day and warned his engineers to be alert. Their main concern, however, was not defense but the construction of a road to Prendergast Ridge.

First Sergeant Jessie H. Clouts, Jr., of Company D, 50th Engineers, was exhausted. "We had worked all night and up until noon of the 27th," he later wrote, "carrying supplies up to the front, then we slept four hours and worked almost all night again. We were so tired when we finally did get into our sacks that I didn't think anything could wake us up, but the 37-mm. shell that smacked through the tent did it." The attack came as a complete surprise. "The shell was the first indication we had that the Japs had broken through. We had just gotten up before they hit us and things really began to pop."

The morning was foggy and dark, Clouts recalled, so it was nearly impossible to tell friend from foe. According to Clouts, one of the company officers saw a man walking out ahead of him and ordered him to "get the hell down in a hole." The soldier turned out to be Japanese. He replied, "Me do,

Me do," but didn't get down fast enough to escape the officer's bullet. "They were right in with us," Clouts said.

Lieutenant Jack J. Dillon and Clouts tried to set up a line and found that their best protection was to walk up straight. They decided to risk stray bullets, "both of us being over six feet tall was pretty good identification for us so our own boys wouldn't shoot us." All morning his company commander shouted directions and pep talks that could be heard, even above the racket of the fight, all over the hill. The unit's two Browning automatic rifles, one on each flank of the line, "got in some good licks with tracer ammunition which marked our own line for our men, and also pointed out targets."

The line held, and few Japanese got through it. At daylight the Americans discovered "a whole bunch" of enemy soldiers trapped in a ditch in front of the road along which they had been fighting. The engineers kept firing to keep the foe down, while several others crawled up the bank and threw grenades into them. "Helmets, rifles, and Japs," Clouts remembered, "flew out of the ditch. We were astonished at the mess of them. They had been lying three deep in the ditch trying to hide."

Company A, 13th Engineers, was on the west side of Engineer Hill below some of the American guns, the main goal of the Japanese counterattack. Lieutenant Robert H. MacArthur of Company A had prepared a defensive plan that went into effect when a guard alerted the company. The engineers moved into a defensive line, but the overpowering Japanese force drove the defenders higher up the slope. Company A finally held firm in a line on top of Engineer Hill and halted the attack.

The action on Engineer Hill was marked by considerable confusion and some panic as the surprised engineers stumbled out of their tents. Company officers and noncommissioned officers hastily organized small groups into makeshift defensive lines. The men fought back as well as they could, lobbing grenades into the darkness from behind tractors and crates or firing their carbines and rifles from piles of earth and rock which they had excavated in the course of road construction. The 13th's machine guns proved highly effective. By noon the routed enemy fled to the gorges on the far side of Sarana Valley. When wounded or cornered, many

of the Japanese killed themselves with their own grenades. By nightfall they had been practically wiped out. Over 250 bodies, many armed only with bayonets tied to sticks, were found around Engineer Hill where the engineers had borne the brunt of the attack.

This deadly charge was the end of organized resistance. On 30 May, the Japanese announced the loss of Attu. For the Americans, the campaign had been costly: losses were about 550 killed, about 1,200 wounded, and approximately 2,100 nonbattle casualties from a ground force that had reached 15,000. The most common nonbattle injuries were exposure and trench foot. Of the Japanese defenders, 2,350 were counted dead and 28 or 29 were taken prisoner.

With Attu secured, full attention turned to the construction program for its use in the neutralization of Kiska and attacks on the Kurile Islands. The first priority was completion of an airfield. The decision had been made not to complete the Japanese runway in Holtz Bay. This runway, which had been started in February 1943, was only half done and not the best airfield site. Lieutenant Colonel Whitesell of the 807th was one of a number of American engineers who inspected the Holtz Bay runway. His judgment, supported by others, was that it would be better to start over than complete this one.

The runway, on the east arm of Holtz Bay, was too close to the ridgeline. A place in the middle of the valley would have been better, but the hillside location was nearer the source of fill material. The center of the valley had a firm gravel base that could have been quickly converted into a runway, but the Japanese did not have heavy equipment to transport fill. They had to build at the source. The work that had taken months could have been completed in five days with the ordinary equipment in an American aviation unit.

Talley and Whitesell judged a site at Alexai Point to be superior to Holtz Bay. The approach to this site was safer and there was more room. Even before Attu was secured, construction started on the airfield. Womeldorff headed this project, with construction accomplished by the 50th and 13th Engineers, Company A of the 807th Engineer Battalion (Aviation), and a detachment of the 349th General Service Regiment.

During the battle for Attu, another airfield site on the nearby island of Shemya was investigated. Colonel Talley led a two-day reconnaissance of this island on 28 and 29 May. Talley sketched out the layout for a bomber runway and hardstands. Shemya later contributed to the missions against the Kurile Islands.

An Attu Island American defense garrison with facilities for 5,956 officers and enlisted men and 2,360 officers and men in the Army Air Force was built by engineer troops and the West Construction Company. The garrison and airfields were done in July 1944. Facilities were built at Massacre Bay, Massacre Valley, Engineer Hill, and Holtz Bay. The combined base area was named Camp Earle in memory of Colonel Edward P. Earle, the commander of the 17th Infantry Regiment, who was killed in action during the 7th Division's assault.

At Attu today, the unfinished Japanese airfield in Holtz Bay is still visible. A few pieces of Japanese construction equipment sit rusting on the runway, and one of the Japanese 75-mm. guns remains as well. So does the abandoned American airfield at Alexai Point. On both sides, the flotsam of war still recalls the hard fought battle of Attu.

Sources for Further Reading

Brian Garfield's dramatic account of the war in the north, *The Thousand-Mile War: World War II in Alaska and the Aleutians* (New York: Bantam Books, 1982), provides a vivid narrative of the battle for Attu.

Also useful for material on the context and on the battle itself are two volumes in the Army's official history of the war. These are Karl C. Dod, *The Corps of Engineers: The War Against Japan* (Washington: Office of the Chief of Military History, 1966), and Stetson Conn, Rose C. Engelman, and Byron Fairchild, *Guarding the United States and its Outposts* (Washington: Office of the Chief of Military History, 1964).

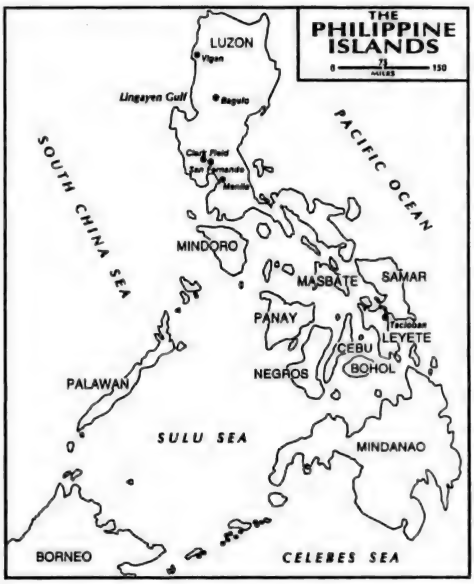
The Liberation of the Philippines

by Martin K. Gordon

By the summer of 1944, the war in the Pacific was going so well that the Joint Chiefs of Staff asked the theater commanders, Admiral Chester W. Nimitz, Pacific Ocean Area, and General Douglas MacArthur, Southwest Pacific Area, about the possibility of bypassing selected objectives in order to accelerate the timetable. At a July conference in Hawaii, MacArthur convinced President Roosevelt that for both moral and strategic reasons American forces had to return to the Philippines. The attack on Leyte was set for December 1944.

In a series of air attacks on the central Philippines in mid-September, Admiral William Halsey's Third Fleet carrier pilots reported weak opposition, and Halsey told Nimitz the area was "wide open." He recommended the immediate invasion of Leyte. When MacArthur agreed, the Joint Chiefs set the Leyte attack for 20 October with Luzon to follow in December. MacArthur was returning to the Philippines.

Leyte, the eighth largest island in the archipelago, was chosen for the initial attack as it is the natural gateway to the rest of the Philippines. The island is 115 miles long and from 15 to 45 miles wide. It has two seasons, wet and dry, caused by the October to April northwestern monsoon. Volcanic in origin, a range of mountains from north to southeast separates the island into the northeast Leyte and northwest Ormoc valleys. Most of the people, the largest cities including Tacloban the capital, and the principal airfields were in the Leyte Valley in the fall of 1944. Tacloban airport was a



Philippine Islands

prewar, 5,000-foot field 2 miles southeast of the capital. Four other smaller fields were located in the vicinity of Dulag in central Leyte Valley. While much of this information was available to the Americans from prewar studies, the latest Japanese situation was partially concealed behind cloud cover, which air photography had little success in penetrating.

However, some information came to MacArthur's headquarters from guerrilla sources, and by the summer of 1944, the Americans knew the Japanese were reinforcing their Philippine garrisons. The Japanese transferred their western Pacific headquarters from Singapore to Manila and developed their Philippine Island brigades to division strength that summer. By the fall, Leyte troop strength, consisting of the 16th Division with service troops, was at the 21,700 level, a force that could increase by adding regiments from neighboring islands. The Japanese had an undetermined number of tanks and armored cars, but their artillery consisted of only coastal defense guns and a few field pieces near Tacloban.

MacArthur's strength, on the other hand, was considerable in air, naval, and ground forces. The ground forces belonged to Lieutenant General Walter Krueger's Sixth Army of two corps: the X Corps with the 1st Cavalry and 24th Infantry Divisions and the XXIV Corps with the 7th and 96th Infantry Divisions. In reserve were the 32d and 77th Infantry Divisions. To provide an efficient construction and logistics organization in the early days of the operation, the theater Services of Supply (SOS) established the Sixth Army Service Command, and the theater engineer, Major General Hugh J. Casey, stepped down to command it. He established his staff around the headquarters personnel of the 5201st Engineer Construction Brigade and, as commander of a unit on a level with the tactical corps, he reported directly to Krueger. The 21,097 engineer troop strength included 15 aviation battalions, 3 construction battalions, 2 port construction and repair groups, and 7 dump truck companies.

Even with this strength, plus the engineers at army, corps, and division level, shortages existed mainly in bridging. The Leyte campaign would require more bridges than had New Guinea, but only the 556th Heavy Ponton Battalion and 530th Light Ponton Company with Sixth Army and the 506th Light Ponton Company with X Corps were available.

The beach assault forces were not short engineer expertise as the 2d Engineer Special Brigade, a Sixth Army asset, was an experienced unit having participated in the New Guinea campaign from May 1943 to September 1944.

The plan required the 2d Brigade to support two major landings across Leyte's east coast beaches: the X Corps' 1st Cavalry and 24th Infantry Divisions were to land near Tacloban while the XXIV Corps' 7th and 96th Infantry Divisions landed further south near Dulag. The assault areas were selected for ready access to airfields, one near Tacloban and four near Dulag. The exploitation portion of the plan had the X Corps advancing northwest to take the airfield and Tacloban and then attacking through the mountains toward the Ormoc Valley. At the same time, the XXIV Corps would drive across the narrow waist of the island, seizing the airfields and then advancing northwest to link with the X Corps in the Ormoc Valley.

The first mission of the Service Command engineers was rehabilitation of the Japanese airfields for American use. They were to prepare one 5,000-foot field for fighters within five days of the landing. The engineers were also to build a logistical support base for 200,000 troops to include port facilities, warehouses, and hospitals. The Service Command engineers were to accomplish all of this within the first 30 days, at which time the theater SOS was to become operational.

To accomplish this mission, General Casey organized his engineers into two subordinate commands: Construction Command would build the airfields and bases while Base K Command would administer the facilities. Not all engineers were in agreement with the plan. Colonel William J. Ely, Sixth Army Engineer executive officer, objected to the construction program objectives during the monsoon season. He argued that the impact of the heavy rains on what was an inadequate road system would make it impossible for the engineers to accomplish their mission in the time allotted unless they were reinforced. As Ely summarized his recommendations, "Perhaps we can mud and muddle through again on a shoestring but the shoestring must be frayed by this time and if it broke we may lose our shirt as well as our shoe." MacArthur's headquarters decided to go ahead with the original plan.

The Sixth Army assaulted Leyte on 20 October 1944 in ideal weather and a calm sea. The 2d Engineer Special Brigade supported the X Corps landings; the 1st Cavalry Division came across White Beach near Tacloban while the 24th Infantry Division used Red Beach just to the south. The amphibious engineers faced serious problems on Red Beach, where the 532d Engineer Boat and Shore Regiment encountered water so swampy and shallow that only one landing craft could unload at a time. Equipment and supplies came ashore under intense Japanese 75-mm. gunfire and, after several craft were hit, the remainder moved to a new landing area in the White Beach sector. This caused problems for the future as supplies piled up on the airfield.

Another problem in the Red Beach sector occurred when the 339th Construction Battalion, on X Corps orders, began building a road through the swamps and rice paddies to Highway 1. They were still working futilely on 21 October when Brigadier General Sam Sturgis, Sixth Army Engineer, came ashore and rerouted the road further south to a drier and ultimately more successful location.

In the XXIV Corps area, the amphibian engineers supporting the 7th and 96th Infantry Divisions encountered a few underwater obstacles which were removed by demolition crews. With good water depth, firm beaches, and little Japanese opposition, the engineers landed bulldozers early in the operation to cut access roads. The engineers unloaded all ships of the initial assault force within the first 44 hours of the landing.

General Casey and some of his staff came ashore in the X Corps area on the first day. Tacloban airfield, the priority objective of the 1st Cavalry, was an existing but inadequate airstrip on the narrow, mile-long Cataisan Peninsula on the right flank of White Beach. The 46th Engineer Construction Battalion reached the site on the first day and wanted to begin realigning the strip 10 degrees to extend it to the 6,000 feet needed for bombers.

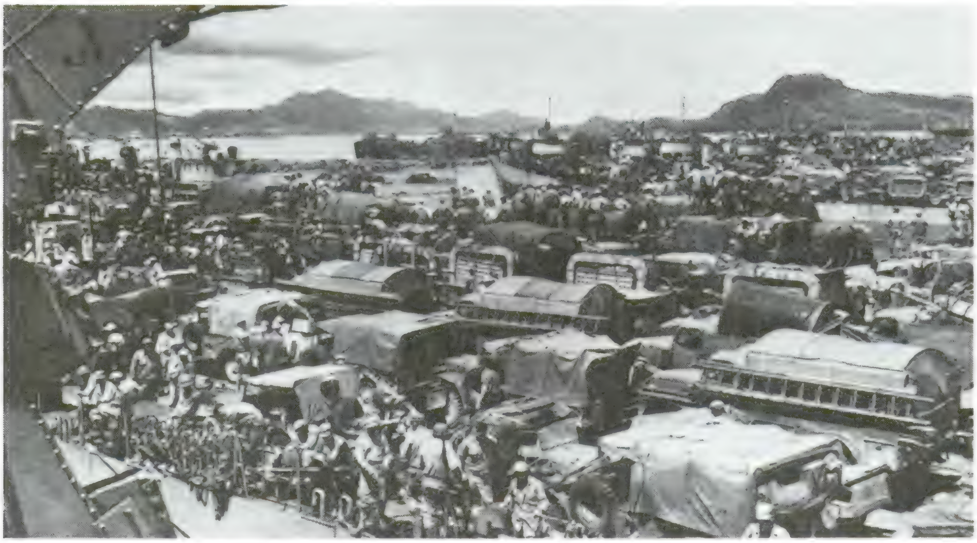
They found work impossible because of the great quantity of supplies and equipment piled on the runway from the landing craft diverted from Red Beach. Efforts to remove the supplies caused traffic congestion which further blocked the engineers and set work back two days. On 23 October,

the 1881st Engineer Aviation Battalion and the 240th Engineer Construction Battalion joined the 46th, and work began on realigning and extending the runway.

The situation turned critical on 25 October when Japanese aircraft attacked the Tacloban field 12 times during the morning as rumors of a great naval battle in Leyte Gulf reached the engineers. Navy planes, whose carriers had been sunk or disabled during the battle, began circling the incomplete strip, searching for a landing place. Many crashed attempting to land, and the engineers had to push some 25 wrecked aircraft into the ocean to keep the primitive runway clear. The engineers serviced and refueled some of the planes so they could reenter the battle as over 65 aircraft used the incomplete runway that day. Working through the night, the engineers had the strip ready for fighters the next day. Then, with the help of the dredge *Raymond*, which pumped sand onto the projected extension to make up for a shortage of coral, the engineers realigned the runway into the bay to achieve the needed 6,000-foot length for bombers.

Meanwhile, in the Dulag area, the engineers were having terrain and weather problems. The 1112th Construction Group reported to General Casey that the airfield locations were in the middle of swamps and rice paddies and that construction would be difficult in the dry season and almost impossible during the monsoon. Even so, the 808th Engineer Aviation Battalion began working on the Dulag strip on 23 October, smoothing the runway and building roads to a nearby gravel pit. On 25 October, about 50 Navy planes from the Leyte Gulf battle used the incomplete runway. Good weather the next two days helped, and on 27 October, the 821st Aviation Battalion joined the 808th. But heavy rains through the end of the month turned the whole area into a sea of mud.

By the end of October, only the Tacloban field was operational, with Dulag finally ready by 18 November. The engineers said no other airfield construction in central Leyte was possible during the monsoon and they recommended east coast locations south of Tacloban. Site selection was so critical that when one was chosen near Tananan, in the Sixth Army headquarters area, General Krueger agreed to move. On 28 November, three aviation battalions began work, and within three weeks a fighter runway was ready.



Diversion of LSTs (landing ships, tank) to the White Beach–Cataisan Point area on Leyte Island seriously impeded construction of the adjacent Tacloban Drome.

On 27 October, the theater air commander had assumed responsibility from the Navy for air support. The lack of airfields reduced air power and allowed the Japanese to reinforce with over two divisions in the Ormoc area. While the campaign developed as planned, the additional Japanese strength made it more difficult and longer than expected.

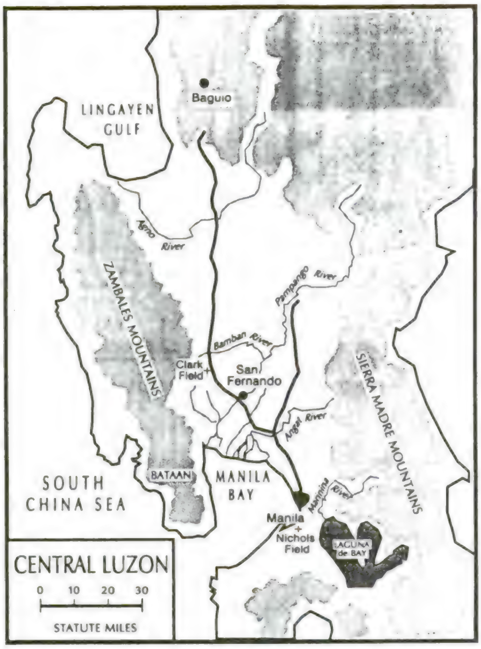
During the prolonged campaign, road construction and maintenance required the most work. In the X Corps area, the three combat battalions could not maintain the roads in the Leyte Valley. Some help came from the 2d Special Brigade engineers who moved supplies along the coast and evacuated the wounded. The advance into the mountains almost came to a halt due to poor roads, but air drops and local porters kept the drive going. In the XXIV Corps area, the 13th Engineers of the 7th Division and the 321st Engineers of the 96th Division built the main supply road through a swamp, using a great deal of corduroy.

The monsoon rains—35 inches in the first 40 days—slowed airfield development, almost destroyed the road network, and made base construction nearly impossible. The lack of airpower and the poor supply lines lengthened the campaign, but finally Eighth Army began the mopping-up phase on 25 December. Sixth Army had another job—Luzon.

Poor drainage, heavy rains, and military traffic made maintenance a problem on Highway 1 going north from Burauen, Leyte Island, 5 December 1944.

The reconquest of Luzon was the largest joint operation of the Pacific war to date, and it was the first Pacific land campaign to provide for the employment of mass and maneuver on a scale even approaching that of the European and Mediterranean theaters. Luzon, rather than Formosa, was approved as the next objective when General MacArthur said that he could mount the operation in December and that he would not need the Pacific Fleet aircraft carriers after the first few days. His engineers would provide a field in the beachhead area for land-based planes, in the event the Luzon landing moved back to January when Leyte lasted longer than expected.

Still, a January date would allow use of the November to May dry season for most of the campaign. Thus, dust rather than mud would be the main irritant for the engineers. Once through the swamps and rice paddies behind the Lingayen Gulf beaches, the engineers would face few natural obstacles other than numerous small streams and rivers in the Central Plains. Highway 3, a two-lane, all-weather, paved road, would provide a 100-mile, high-speed approach to Manila with only the Agno and Pampanga rivers as significant potential problems.



Central Luzon

While prewar experience helped the Americans in the terrain and weather area, air photos and the guerrilla information network gave them a good idea of the Japanese defense scheme. General Tomoyuki Yamashita, 14th Area Army commander, had available a force of about 275,000 troops in his one tank division, some seven infantry divisions, and Naval and Air Corps units. Short of supplies, equipment, and transportation, Yamashita organized three groups in static defensive positions in the mountains.

To confront the Japanese defenses, General Walter Krueger's Sixth Army had I Corps with the 6th and 43d Infantry Divisions and XIV Corps with the 37th and 40th Infantry Divisions. In reserve he had the 25th Infantry Division and the 1st Cavalry Division. The 4th Engineer Special Brigade, reinforced with two boat and shore regiments, would put this force across the Lingayen Gulf beaches. General Casey's Service Command had only nine engineer aviation battalions, but General Sturgis' Sixth Army engineers had six of them plus the 5202d Construction Brigade. However, the engineers were short in the bridging area with only one heavy ponton battalion and three light ponton companies available.

General Krueger planned to land his Sixth Army across the Lingayen Gulf beaches, drive down the Central Plains to seize Manila and the forts in Manila Bay, and then go into a mopping-up phase. During the advance, the engineers planned for repeated use of floating bridges, leapfrogging them forward and replacing them with semipermanent structures. Sturgis put one light ponton company with each corps and kept one, plus the heavy battalion, at Sixth Army. In addition he had all engineer battalions carry 150 feet of double-lane Bailey bridging and 200 feet of timber trestle.

Service Command's first project was construction of a temporary 5,000-foot runway in the beachhead area within six days of the landing. Within the first 15 days they were to have ready two all-weather strips. In addition, the Service Command was responsible for constructing Base M at Lingayen to support the drive down the Central Plains.

The Luzon campaign started on 9 January 1945 when the 4th Engineer Special Brigade brought the Sixth Army ashore over a 15-mile series of beaches in Lingayen Gulf. The 544th Engineer Boat and Shore Regiment supported the XIV Corps' 37th Infantry Division on Yellow Beach while the 594th Engineers supported the 40th Infantry Division on Orange Beach. In the I Corps area, the 543d Engineers were in support of the 6th Infantry Division on Blue Beach while the 533d moved the 43d Infantry Division across White Beach. Opposition was light with fewer casualties among the amphibian engineers than for the Leyte operation.

General Casey's Service Command was to function as the Sixth Army construction agency for the first month of the operation. Casey came ashore on 10 January with a first priority to construct a fighter strip in the beachhead area. He immediately put 400 Filipino civilians to work filling bomb craters on a damaged Japanese strip near the town of Lingayen. On 13 January, the 836th Construction Battalion began work, and on 14 January, the 1879th Aviation and the 43d Construction Battalions reinforced them. Little earth moving was necessary, so the engineers smoothed the surface, covered it with palm fronds, and placed steel mats on top. By 16 January, a 5,000-foot runway was ready. Meanwhile, two other strips were built by Service Command aviation battalions during the first two weeks of the operation, thus freeing the aircraft carriers for return to the control of Pacific Fleet.

In constructing Base M, Service Command engineers built gasoline storage tanks and rehabilitated a wharf on the banks of the Dagupan River. They also improved and maintained over 40 miles of road, and rehabilitated 35 miles of railroad before they went out of business on 13 February. When the SOS took over, Casey returned to his position as theater engineer.

Meanwhile in the drive south through the Central Plains, the XIV Corps was on the right pushing toward Manila with I Corps on its left protecting the flank from strong Japanese forces in the mountains. The XIV Corps' 40th Division, with its own 115th Engineers and the corps' 530th Light Ponton Company followed Highway 3 toward Manila. The division crossed the Calway and Agno rivers using engineer assault boats, and when it reached the Tarlac River, the engineers repaired a poor Japanese bridge demolition effort in two hours. Within two weeks, the 40th Division reached Bamban, halfway to Manila. The corps' other division, the 37th, crossed the Calway River on a bridge repaired by its own 117th Engineers with help from the 530th. On the 16th, the engineers repaired a railroad bridge over the Agno River and built 8-ton and 16-ton ponton bridges.

In the I Corps area, the 6th Infantry Division's 6th Engineers built a 150-foot Bailey bridge over the Binlac River. By 20 January the division was over the Agno River using a ponton bridge built by the 6th Engineers with help from the 506th Light Ponton Company, a Sixth Army unit. The 43d Division had little trouble in its area using railroad bridges reinforced for heavier loads by the 118th Engineers.

The Sixth Army's 5202d Engineer Construction Brigade used the 556th Heavy Ponton Battalion, the 506th Light Ponton Company, and the 1011th Treadway Bridge Company to put a steel treadway over the Calway River and a ponton and a treadway over the Agno at Wawa by 20 January. The 5202d's aviation battalions built semipermanent bridges and repaired demolished bridges along the roads of the Central Plains and restored most of the bridges on the Manila railroad as well. By 29 January, the railroad was open from Lingayen to Tarlac, halfway to Manila.

During the rapid advance south, combat engineer missions were almost exclusively river and stream crossings. It was not until the drive reached the Clark Field–Fort Stotsenburg area, that the engineers encountered any significant Japanese mine warfare attempts. There, the 117th Engineers removed almost 1,300 aerial bombs used by the Japanese in a rather ineffective minefield. Once the covering fire was subdued, engineers, using A-frame pulleys mounted in trucks, removed the bombs by disarming them and pulling them out.

On 31 January, the 1st Cavalry Division was committed in the XIV Corps area for the drive to Manila. With the 1st Cavalry on the left and the 37th Division on the right in the swampy terrain, the drive got underway on 1 February when the 37th crossed the Pampanga River at Calumpit using 117th Engineer driven M-3 rafts. Since the rafts could not carry heavy equipment, the 556th Heavy Ponton Battalion began installing a treadway bridge. Joined by the 530th Light Ponton Company on 3 February, the engineers had the bridge ready for loads up to 16 tons by the next day. In the last 30 miles before Manila, the 530th installed seven bridges of more than 150 feet each for the 37th Division.

On the left flank, the 1st Cavalry avoided the swampy terrain; and after it crossed the Pampanga River near Cabanatuan on 1 February, using a wooden trestle bridge repaired by its 8th Engineer Squadron and the 1011th Treadway Bridge Company, only the Angat River remained between it and Manila. That obstacle was crossed on 2 February over a treadway built by the 8th Engineers and the 556th Engineers. The 1st Cavalry reached the northern outskirts of Manila in the early evening of 3 February.

The Japanese withdrew south of the Pasig River, destroying all the bridges in the process, to defend the government buildings and the old walled section—Intramuros. By 6 February, the 1st Cavalry and the 37th Divisions controlled all of northern Manila while the 11th Airborne Division, which had landed at Nasugbu on 31 January, approached the city from the south.

Infantry support rafts on the Pasig River.

The 117th Engineer Combat Battalion ferried the 148th Infantry, 37th Division, across the Pasig on 7 February using 30 assault boats in five waves. The last 4 boats came under intense enemy small arms, mortar, and artillery fire. The next day, the 530th Light Ponton Company, with the help of the 117th, after several delays caused by Japanese fire, threw a 350-foot bridge across, completing it under cover of darkness.

The Japanese, in strong defensive positions, used land mines profusely as they fought tenaciously for each building. Suffering casualties trying to remove the mines in defended areas, the engineers changed their approach to an engineer–tank–infantry team method. While riflemen in buildings on both sides of a street suppressed the Japanese covering fire, a tank, with a tow cable attached to the front, moved toward a mined area, all weapons firing. An engineer four-man mine disposal unit followed closely behind. Upon reaching the mined area, the tank stopped firing its main gun, but continued to fire its machine guns. An engineer then rushed from behind the tank to the nearest mine, disarmed it, and attached it to the tow cable. The tank then pulled out the mine by backing away. With this type of fighting, it was not until 3 March that the Sixth Army could declare Manila free of Japanese defenders.

With that declaration, a city rehabilitation effort moved into high gear. A task force construction command of eight engineer units, the advance echelon of the 5202d Engineer Construction Brigade, was organized on 1 February. Units assigned included the 43d Construction and 1876th Aviation Battalions, the 1504th Water Supply and 963d Maintenance Companies, a depot platoon, a utilities detachment, and elements of a heavy ponton battalion. Their mission included installing floating bridges, clearing streets, rehabilitating and operating the municipal water and electrical systems, fighting fires, and demolishing unsafe buildings.

On 6 February, the task force moved into northern Manila with its first priority the rehabilitation of the water supply system to see the city through the remainder of the year's dry season. Fortunately, the engineers reached the reservoirs before the Japanese could destroy them. But, because of battle damage and years of neglect, the water supply pipes had

Engineers cut steel reinforcers in concrete from the Manila City Hall building. Here Major General Hugh J. Casey speaks to PFC Perry Alexander, a welder with the 1879th Engineer Aviation Battalion, 23 March 1945.

thousands of leaks, making them unreliable. Establishing water supply points for both soldiers and civilians, even while fighting was raging in the city, the engineers and rehired water system employees were able to keep water distributed throughout the city while they repaired or replaced the pipes.

The enemy had more thoroughly demolished critical parts of the electrical system, leaving the city without electricity. Beginning with temporary power sources, such as the generating units of a local brewery, the engineers rehabilitated the power distribution system as they restored generating facilities. They also demolished weak structures, repaired the streets and docks, and reestablished the fire department. In rehabilitating the city, they began to repair the immense destruction caused by both Japanese destruction efforts and the fighting needed to recapture the city.

Fighting continued on Luzon even as the engineers worked in Manila. In the mountains, the Japanese held out in strong defensive positions and combat engineers had to use armored bulldozers to keep the trails and roads open during the monsoon season. At times, they provided their own

infantry cover while clearing well-defended minefields. It was mid-June before southern Luzon was cleared; and on 1 July, when the Eighth Army began the mopping-up phase, there were still almost 65,000 Japanese troops scattered throughout the mountains of northern Luzon. Sporadic fighting continued to the end of the war on 14 August 1945.

Sources for Further Reading

The following are suggested additional readings on the liberation of the Philippines. Karl C. Dod, *The Corps of Engineers: The War Against Japan*, *United States Army in World War II* (Center of Military History, 1966), and *Put 'Em Across; A History of the 2d Engineer Special Brigade, 1942–1945*. Studies in Military Engineering, Number 2. Reprint (Fort Belvoir, VA: Office of History, U.S. Army Corps of Engineers, 1988).

Another study is from the Office of the Chief Engineer, General Headquarters, Army Forces, Pacific. *Engineers of the Southwest Pacific, 1941–1945: Volume I, Engineers in Theater Operations* (Washington, DC: Army Forces, Pacific, 1947).

James B. Lampert's article, "Combat Engineering—Lingayen to Manila," *Military Engineer*, Volume 38, Number 246. (April 1946) pp. 143–148, is only one of many about various phases of combat in and the reconstruction of the Philippines in the 1945–1947 issues of this magazine. Kenneth J. Deacon published a one-page series titled "Combat Engineers" in this magazine between 1960 and 1965 that the serious researcher should consult.

Cave Warfare on Okinawa

by Dale E. Floyd

By the fall of 1944, the United States was in the final phase of its war against the Empire of Japan. The ultimate goal of American operations in the Pacific was the industrial heart of Japan, the south coast of Honshu. Throughout most of 1944, the Americans planned an invasion of Formosa, Operation CAUSEWAY, to support the attack on the Japanese home islands. When General Douglas MacArthur, Commander in Chief, Southwest Pacific Area, attacked Leyte in October rather than December, Admiral Chester Nimitz, Commander in Chief, Pacific Ocean Area, felt that the possibility of an early advance into the central Philippines opened a direct approach route north through the Ryukyus rather than by way of Formosa.

Thus was born Operation ICEBERG, the attack on the largest of the Ryukyu Islands, Okinawa. The island was within medium bomber range of Japan and, with airfield construction, could sustain a force of 780 bombers. Good fleet

Okinawa Island Group

anchorages were available in the Okinawa island group, and from these air and naval bases the Americans could attack the home islands and support the invasion of Kyushu and finally Honshu.

Okinawa is 69 miles long and from 2 to 18 miles wide, comprising a total area of 485 square miles. With a subtropical climate, Okinawa's temperatures range from 60°F to 83°F, and high humidity makes it oppressive during the monsoon season from May to November. This rough, generally mountainous coral island has two types of terrain. The northern part, roughly two-thirds of the island, is generally rocky with a high ridge running its length covered with forests and heavy undergrowth. The southern one-third of the island, where most of the people live and practically all cultivation occurs, comprises rolling hills dotted with deep ravines and sharp limestone ridges.

American knowledge of the terrain and enemy situation was acquired over a period of months and with some difficulty. While limited information was gathered from old publications and captured documents, the bulk of the data came from aerial photos. The engineers constructed models of particular objectives based on intelligence and reconnaissance work, including a highly accurate one of the Mount Shuri/Shuri Castle area, that would be the most heavily defended real estate in Okinawa. With cloud cover hindering full coverage, the 1:25,000 scale target map had incomplete detail, especially in the south.

It was in the south that Lieutenant General Mitsuru Ushijima, Japanese 32d Army commander, decided to make his stand. As a beach defense would subject his troops to murderous American naval gunfire and a defense in the north would not deprive the Americans of the airfields and harbors of the south, Ushijima determined that the best use of the force available to him was a defense of southern Okinawa.

Southern Okinawa, south of Kuba on the east coast, was ideally suited for defense. The soft limestone ridges included numerous caves with natural cover and concealment. The Okinawans had converted some of the caves into burial tombs.

The Japanese, already known as tenacious fighters, would maximize their capabilities by establishing a strongpoint

defense utilizing cave warfare. Lieutenant General Isamu Cho, General Ushijima's chief of staff who was one of Japan's foremost experts on strongpoint defense, took overall charge of the defensive operations. Japanese unit commanders from brigade to company level determined the location and design of defenses in their own sector while subordinates oversaw actual construction at particular sites. Reserve units set up antiaircraft defenses.

In August 1944, the Japanese began in earnest to construct their defenses. Besides their own men, commanders used Okinawa home guards, called Boeitai; attached labor personnel; and local village conscriptees, including school children, to do the work. In adapting the defense to the terrain, the Japanese built blockhouses and pillboxes into the hills and fortified the natural caves, even the tombs.

Some of the hundreds of fortified caves were more than one-story high. Practically every cave had multiple exits and tunnels connecting to other caves. For the first time in the Pacific war, the Japanese had adequate artillery and mortars that they thoroughly integrated into the defenses. The size of cave exits varied but most were small, even as little as two feet square, to escape detection because they doubled as weapons embrasures and to provide as little space as possible for the entry of enemy artillery shells.

Although the Japanese generally lacked concrete and steel for cave lining, some of the latter was available for covering entrances. Logs often shored up the caves. Once inside the small entrances, the caves opened up into larger spaces, often comprising more than one room. Some caves had separate rooms for various purposes including barracks, mess, ammunition storage, and radio transmission.

The main defensive positions were on the reverse slopes. All of the defenses, including the ordnance, were cleverly camouflaged. After the construction work ceased, the Japanese placed mines and booby traps in their defenses.

Although few enemy minefields existed, the Americans did discover effective ones at crucial tank approach points such as road junctions, turnoffs, and defiles. The Japanese used a newly developed mine on Okinawa—an antipersonnel fragmentation mine that the rocky terrain made difficult to detect. They also dug ditches and created tank traps covered

by supporting fire. From the time an American tank entered an avenue of approach, it was under constant attack from direct and indirect fire.

Manning the defenses was the Japanese 32d Army. Its infantry strength consisted of the 62d and 24th Divisions, the 44th Independent Mixed Brigade, and some converted naval units. A tank regiment, four machine gun battalions, and four artillery regiments supplemented the divisional units. The artillerymen, veterans of several campaigns, were considered among the best in the Japanese army. Conscripted Okinawans and the Boeitai were forced to serve with the army. At the time of the American attack, the 32d Army strength was over 100,000 men.

On 1 April 1945, Easter Sunday and April Fool's Day, the American Tenth Army assaulted the island of Okinawa. The Tenth Army consisted of two corps: the XXIV Corps had three Army divisions, the 7th, 77th, and 96th, and the III Amphibious Corps had three Marine divisions, the 1st, 2d, and 6th. Operation ICEBERG required an attack directly across the island to capture the two airfields and split the enemy force. Then, while the Marines held in the north, XXIV Corps would attack and overrun Japanese defenses in the south. Once that was accomplished, they would attack the Japanese forces in the north.

The Japanese expected the Americans to use the good west coast beaches and immediately strike out for the nearby airfields, Yontan and Kadena. A week before, the American 77th Division had seized the Kerama Islands as a fleet anchorage and the Keise Islands as an offshore artillery platform for the Okinawa beach assault. Thus, the Japanese did not defend the beaches and the Americans quickly seized the two airfields and cut the island in half. By 3 April, it was clear to Lieutenant General Simon B. Buckner, Jr., Commanding General, Tenth Army, that there were few Japanese in the north. In a change of plans, he sent the Marines there while at the same time he pushed the XXIV Corps south toward the main Japanese defenses.

While the Japanese high command was determined to hold Okinawa and intended to use bomb-laden planes guided to naval targets by suicide pilots, the navy's Kamikaze Corps, General Ushijima was more realistic and decided that the

best he could do was to hold out for as long as possible and inflict maximum casualties. He made his stand on strongly fortified, concentric defense lines constructed in the south around the Shuri Heights high ground. In accordance with Japanese defense doctrine, each position protected its own location as well as an adjacent one; the key was mutual support through coordinated fire.

The 96th Division reached the first Japanese defense line, Kakazu Ridge, by 8 April. The next day, in a surprise attack without artillery support, the 383d Infantry Regiment made a frontal assault. It seized the forward slope and reached but could not hold the ridge line. The reverse slope defense system of pillboxes, tunnels, and caves with machine guns, mortars,

Japanese caves and dugouts honeycomb a hillside on the banks of the Bisha Gawa River.

and artillery covering all avenues of approach was too strong for a direct infantry attack. This attack taught the Americans that the key to success was an attack on the reverse slope defenses while a large force engaged and prevented the forward slope defenders from providing any support.

The next attack on the Kakazu Ridge line was corps-size with the 7th and 27th Divisions added to the 96th. From 18 to 24 April, these XXIV Corps units supported by 29 artillery battalions plus air strikes and naval gunfire fought the Japanese along this initial defense line. The 102d

Engineer Combat Battalion built a foot bridge, two Bailey bridges, and a ponton bridge to place the 27th Division in position for an attack. The 7th Division, even though supported by the first use of armored flame throwers of the 713th Tank Battalion, was unable to dislodge the Japanese from reverse slope positions along Skyline Ridge. By 20 April, only the 27th Division was in position to attack into the rear of the Japanese defense line; the 7th and 96th Divisions would have to continue the frontal attacks.

The rear of the Kakazu Ridge was the 27th Division's target. The 102d Engineers sealed Japanese caves along the forward slopes of the Pinnacles, depriving the reverse slope defenders of covering fire. On 24 April, the Japanese began an orderly withdrawal from the outer Shuri defense as their line was penetrated and the strongpoints battered.

American veterans of the Pacific war recognized the techniques and tactics of the Japanese defense: intricate and elaborate underground positions, and full use of cover and concealment soundly based on a reverse slope concept. They had experienced it all the way from Guadalcanal to Leyte. But on Okinawa, the Japanese used all their experience to produce the strongest defense the Americans confronted in the Pacific war.

An armored flame thrower tank from the 7th Infantry Division, Tenth Army, attacks Japanese cave defenses on Hill 178, 21 April 1945.

during the entire campaign on Okinawa and the nearby islands. General Buckner called this the "blowtorch and corkscrew" method; the blowtorch was the liquid flame and the corkscrew was the explosive.

When possible, the demolition squad obtained a foothold above a cave opening and attacked down the hill in what were termed "straddle attacks." This method denied the defenders direct fire against the attackers. In all instances, mutual supporting defensive fire had to be silenced before the demolition squads could go into action. The tanks and infantry waged the battle, but frequently it was the flame and demolition that destroyed the position.

The Tenth Army included all of these attack methods in the tactics of an Army-size assault on the Shuri defense system. Since the northern operations were over, the Marines and the 77th Division came south. Then, with the III Amphibious Corps on the right and the XXIV Corps on the left, the Tenth Army planned an attack to double envelope the final Shuri line.

As the Americans were getting into position, the Japanese counterattacked on 4 May. When General Ushijima realized that the Americans were not going to conduct an amphibious operation in the south, he moved the 44th Independent Mixed Brigade and the 24th Division into the Shuri area. With that additional strength, he chanced an attack to try to push the Americans off the island. By 8 May, he knew he had failed, and on 11 May, the Americans resumed the offensive.

In the center of the line, the 77th Division and the 1st Marine Division had slow going in frontal assaults on strong Japanese positions. The 77th Division brought all available fire to bear on limited objectives, seized forward slopes to clear reverse slope covering fire, and expended huge amounts of gasoline and napalm to seal Japanese defensive positions as it fought south along Route 5 through hills given American names such as Chocolate Drop and Flattop. The 1st Marine Division attacked the Shuri Heights and, in spite of the fortified caves, made steady progress by concentrating on one specific objective at a time. The Marines called it "processing." By 21 May, both divisions were ready to break into the final Shuri position.

The enemy flanks were now the key to success for the Americans. On the right, the 6th Marine Division had a difficult fight taking two flanking hills before they could get tanks into the rear of Sugar Loaf Hill and reduce the Japanese reverse slope positions. The seizure of Sugar Loaf opened the way into the rear of the Shuri defenses from the right.

When the 96th Division took Conical Hill on the left flank, the Shuri rear area was open to attack. By 21 May, the possibility of a double envelopment of Shuri existed. Then the rains came.

General Ushijima knew his position was untenable so, under cover of the rain, he began his withdrawal from the Shuri defense system on 22 May. By 31 May, the Americans occupied Shuri, but the Japanese made good the escape of some of their force to a final defense position on the southern tip of the island.

The Americans continued the drive south and by 9 June were in position to attack the final Japanese defenses—the Yaeju Dake Escarpment. The terrain there was good for armor. The tank–infantry teams and the demolition squads were more experienced and the Japanese artillery was depleted. But some of the largest cave defensive positions were in the area. It took the Americans three weeks to reduce the Yaeju Dake. No wonder that in one month of fighting on Okinawa, the combat engineers in the three regimental zones destroyed 1,000 Japanese caves, pillboxes, bunkers, and defensive positions. Organized resistance was declared over on 21 June.

The Okinawa campaign proved to be expensive in men and materiel. In the final days, four general officers were killed. On 18 June, General Simon B. Buckner, Jr., was killed by artillery fire, and the next day Brigadier General Claudius M. Easley, assistant commander of the 96th Division, was killed by machine-gun fire. On 22 June, Lieutenant Generals Ushijima and Isamu Cho committed suicide.

American divisions formed a skirmish line on 23 June across the island and began moving south in a final mop-up. The Army either dug out or sealed the remaining Japanese in caves, pillboxes, and tombs. On 26 June, the 321st Engineer Combat Battalion of the 96th Division used 1,700 gallons of gasoline and 300 pounds of dynamite to seal a cave which

reportedly served as the headquarters of the Japanese 24th Division. Finally, on 2 July 1945, Lieutenant General Joseph W. Stilwell, the new commander of the Tenth Army, declared the Okinawa campaign over.

On Okinawa, the engineers played a major combat role in addition to their normal supply and construction duties. Some engineer units had significant losses: the 302d Engineer Combat Battalion sustained 20 percent casualties in one three-week period. Of the total force on Okinawa when the fighting ended, approximately 31,400, or 18.6 percent, were engineer troops. The victory on Okinawa was made possible by the combat accomplishments of the engineers.

Sources for Further Reading

Good full-length studies of the Okinawa campaign include the official U.S. Army history, Roy E. Appleman, James M. Burns, Russell A. Gugeler, and John Stevens, *The War in the Pacific; Okinawa: The Last Battle*, in the *United States Army in World War II* series (Washington, DC: The Government Printing Office, 1948).

Karl C. Dod, *The Technical Services; The Corps of Engineers: The War Against Japan*, in the *United States Army in World War II* series (Washington, DC: The Government Printing Office, 1966), and Leigh C. Fairbank, Jr., "Division Engineers: Part IV, Ryukyus Islands (Continued)," *Military Engineer*, 39, July 1947, 294–99, address the Army engineers' participation in the campaign.

SECTION VII

Combat Engineering: War in Europe

When the United States declared war against Germany on 11 December 1941, American planners had already agreed with their British counterparts on a war strategy: the main effort would be made first against Germany. Unable to get the British to agree to a cross-channel operation in 1942, the Americans accepted a proposal for an invasion of North Africa in November 1942—the first step in what would become the strategy of indirect approach to Europe through the Mediterranean.

Operation TORCH, the invasion of North Africa on 8 November 1942, saw the initial use of a special type of engineer unit, the amphibian engineers. Organized to move troops and equipment from ships across the beaches and inland, these special engineers would go on to play a crucial part in all European amphibious operations. Another new engineer unit, the aviation engineers, got its baptism of fire in North Africa. Structured to build airdromes close to the front for the faster and heavier planes of World War II, the aviation engineers also went on to contribute significantly in all European campaigns.

As the Mediterranean campaign continued through 1943 and into 1944, the engineers traded hot and dusty Sicily for cold and wet Italy. In both places the engineers successfully paced advances through rugged mountainous terrain made even more difficult by tenacious German withdrawal tactics. The Bailey bridge proved to be a technological wonder while the bulldozer became a true friend of the combat as well as the construction engineer.

In the Normandy invasion on D-day, 6 June 1944, engineer beach assault teams paid a heavy price in breaching Hitler's West Wall. After the breakout from the beachhead, engineers aided the fast-moving columns over the roads and across the rivers of France right up to the border with

Germany. There the Germans regrouped and held and finally counterattacked. The Ardennes counteroffensive saw the engineers used to create obstacles in the path of the German attacking forces as well as in their secondary role as infantry. The numerous combat engineer units located along the front helped to hold the line in the Battle of the Bulge until the Allied reserves could react.

As the final drive began in the spring of 1945, engineers bridged the Rhine River. They helped seize the bridge at Remagen, built several bridges in the area, and supported Third and Seventh Army crossings with bridges built under fire. On 7 May, Germany signed the act of unconditional surrender, and the European phase of World War II was over.

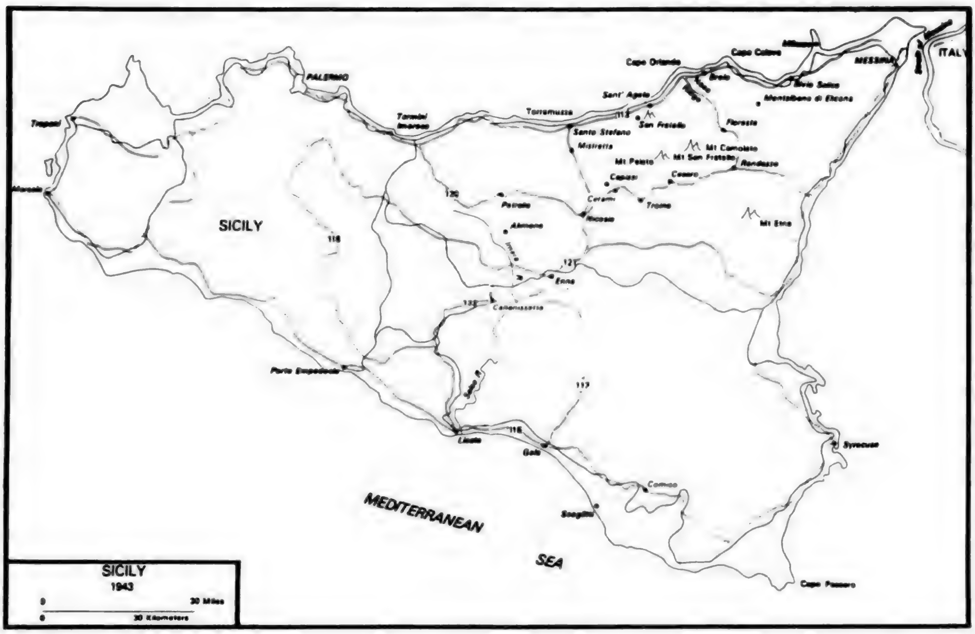
The first two essays describe combat engineer activities in the Mediterranean theater. The remaining essays cover combat engineering in the European theater of operations, beginning with the difficulties of OMAHA and UTAH beaches, through the dark period of the Belgium Bulge, to the successes of the Rhine River crossings.

Engineers in Sicily

by James W. Dunn

The British and American Chiefs of Staff agreed at Casablanca in January 1943 that Sicily would be the next target in the Mediterranean theater upon completion of the Tunisian campaign. By that time in the European war, the Allies had the initiative. Before, they had been reacting to Axis moves, but with El'Alamein, Stalingrad, and the expected successful completion of the campaign in North Africa, the Allies were ready to make the Axis react.

With the British not ready to cross the Channel in 1943, the move against Sicily would continue the indirect approach through the Mediterranean to the continent, keep the pressure on Germany, help the Russians by diverting German forces from the eastern front, and make use of the Allied forces available in the Mediterranean theater. Seizure of Sicily would secure the line of communication through the Mediterranean Sea and intensify the pressure on Italy, possibly knocking it out of the war.



Sicily, 1943

Sicily, 90 miles across the Mediterranean Sea from North Africa, was only two miles across the Strait of Messina from the Italian peninsula. Shaped like a great triangle, it encompassed an area of about 10,000 square miles, roughly the size of Vermont. Mountains, which made up most of the island terrain, dropped abruptly to the sea in the north but sloped gently toward the south. The Plain of Catania in the southeast was the only sizeable stretch of flat land, and on the north it abutted Mt. Etna, a 10,000-foot-high volcano.

There were numerous beaches of sand and shingle, but high ground behind dominated most exits. The best roads were near the coast with interior roads being narrow and winding. The best airfields were also near the coast; none were more than 15 miles inland. The four major ports were Messina in the northeast, Catania and Syracuse on the southeast coast, and Palermo in the northwest corner. Minor ports such as Gela and Licata on the southwest coast were not capable of handling the tonnage necessary to support a major military operation.

Summer weather in Sicily was hot and dry with temperatures often nearing 100°F. There was little rainfall, and dust rather than mud would be a problem for the engineers. While dry riverbeds would prove no hazard to movement, the lack of rainfall would require the engineers to supply significant quantities of water.

In Sicily, the Italian Sixth Army commander, General Alfredo Guzzoni, had four field divisions and six static coast defense divisions. Added to this force were the militia, air, and naval personnel for a total of about 200,000 Italian troops available for defense. The Allies rated the combat effectiveness of this force as poor.

As the Tunisian campaign came to a close, Mussolini asked the Germans to reinforce the Sicily defense force; and Field Marshall Albert Kesselring, Commander in Chief, South, sent the 15th Panzer Grenadier Division and the Hermann Goering Panzer Division. Both units were reconstituted from troops that had not been able to get to Tunisia before the surrender, but their combat effectiveness was considered to be good. While the Germans were officially under Guzzoni's command, General Fridolin von Senger, the German liaison officer, was really in command. There was only cooperation with the Italians.

The Italian coast defense divisions, organized in a widely separated system of forts, were not expected to put up much of a fight; so Guzzoni placed two field divisions in the west and two in the east as counterattack elements. At Guzzoni's request, von Senger placed the Hermann Goering Division, with its battalion of Mark VI "Tiger" tanks, in the southeast and the 15th Panzer Division in the northwest.

General Dwight D. Eisenhower, Supreme Commander, Mediterranean Theater, commanded the Allied forces involved in the Sicily operation. His ground element, General Sir Harold R.L.G. Alexander's 15th Army Group, contained General Sir Bernard Montgomery's British Eighth Army and Lieutenant General George S. Patton's American Seventh Army. Patton organized his army into two operational units. The II Corps had the 1st and 45th Infantry Divisions, while the 3d Infantry Division was separate and reported directly to Patton.

For the landing phase, engineer units of Colonel Eugene M. Caffey's 1st Engineer Special Brigade supported the assault divisions. The 36th Engineer Combat Regiment, under the command of Lieutenant Colonel George W. Gerdes, was with the 3d Division, while Colonel Roland C. Brown's 531st Engineer Shore Regiment supported the 1st Division and Colonel Charles H. Mason's 40th Engineer Combat Regiment supported the 45th Division. Colonel George W. Marvin's 540th Engineer Combat Regiment was in Seventh Army reserve.

The engineers had much better beach assault equipment in Sicily than they had the previous year for the North African landing. The new landing craft were flat bottomed, which allowed them to get close enough to the shore to put men and equipment into shallow water. The landing ship, tank (LST) could carry 1,900 tons or 20 medium tanks and used the landing craft, tank (LCT) as a lighter. The landing craft, vehicle and personnel (LCVP) could carry 36 combat-equipped infantrymen or 8,000 pounds of cargo. Bridging the gap between the supply ships and the dumps on the beach was the 2 1/2-ton amphibious truck (DUKW). It could carry 25 troops and their equipment or 5,000 pounds of general cargo. Capable of speeds up to five knots in water and 50 miles per hour on land, it proved of great benefit to the 1st Engineer Special Brigade.

D-day was set for 10 July 1943 when at 0245 the Allies would begin the simultaneous landing of eight divisions across a 100-mile front in the southern corner of Sicily. While Messina was considered too strong for a direct attack, the Eighth Army zone on the southeast side in the Gulf of Noto did have the major ports of Catania and Syracuse. Patton's Seventh Army, landing across the Gulf of Gela beaches on the southwest side, would have to use minor ports and over-the-beach supply for a time.

General Patton planned to attack with the 3d Infantry Division, under Major General Lucian K. Truscott, Jr., on the left. Truscott's mission was to protect the left flank against counterattack and seize the town and port of Licata and the nearby airfield. In the II Corps area on the right, Major General Omar N. Bradley had Major General Terry Allen's 1st Infantry Division on the left and Major General Troy H. Middleton's 45th Infantry Division on the right. The 45th was to capture Comiso and Biscari airfields and the high ground beyond the beaches, while the 1st Division was to take the town and port of Gela and the nearby Ponte Olivo airfield. To assist the 1st Division, Patton gave to Allen Colonel James Gavin's 505th Parachute Regiment, which was to land at midnight and secure the high ground behind the beaches. Allen also had Force X, a special grouping of the 1st and 4th Ranger Battalions and the 1st Battalion, 39th Engineer Combat Regiment, under the command of Lieutenant Colonel William O. Darby. Darby's mission was to seize and hold the town of Gela.

Colonel Garrison H. Davidson's Seventh Army engineer plan included the normal missions but placed special emphasis on water and bulk fuel supply. To provide one gallon of water a day for each man in Seventh Army, the engineers equipped 20 LSTs to carry 10,000 gallons of water each and planned to pump it ashore into canvas storage tanks. For bulk fuel, the Seventh Army petroleum engineer staff officer organized a system to pump fuel from offshore tankers to beach storage tanks and thence to the airfields and inland depots. With the Seventh Army dependent on over-the-beach supply for up to 30 days, Davidson's plan envisioned that the 1st Engineer Special Brigade, once it regained control of its units when the beachhead was consolidated, would function as a base section.

The Seventh Army landings began at 0245, 10 July, with the 1st and 3d Divisions on time, but high winds and heavy surf delayed the 45th landing for an hour. The same bad weather scattered Gavin's paratroopers all across the front. All the assault divisions attached a platoon of engineers to the assault battalions to clear paths through obstacles and help move the infantry across and beyond the beaches.

The 3d Division had little trouble with the Italian defenders, and by 0500, the 36th Engineers began landing medium tanks and other heavy vehicles across the beaches north of Licata. The 36th Engineer headquarters opened at 0714, and by noon, the supply dumps were operating. Company C supported the 15th Infantry Regiment and the 3d Ranger Battalion in seizing the port of Licata and had it operational by 1600.

By the time the 45th began to land, about 0345, the Italian defenders were alert and ready. As the division's 120th Engineer Combat Battalion cleared paths through beach obstacles, the 40th Engineer Combat Regiment attacked pillboxes defending the exit roads. During this action, two officers and two enlisted men from the 40th Engineers earned the Distinguished Service Cross. At noon, the 19th Engineer Combat Regiment began landing and preparing for its mission to repair the Comiso and Biscari airfields.

In between the 3d and 45th Divisions, the 1st Infantry Division hit its beaches on time. Company C of Lieutenant Colonel William B. Gara's 1st Engineer Combat Battalion supported the 26th Infantry Regiment, while Company A worked with the 16th Infantry on the beaches south of Gela. Colonel Darby landed his two Force X ranger battalions on either side of Gela and put the 1st Battalion, 39th Engineer Combat Regiment, directly into the town. By 0325, the engineers were knocking out gun emplacements on the bluffs overlooking the beach. Entering Gela, they found that the best way to clear the streets was to throw a high explosive grenade down the street to create a dust cloud and then advance behind the cloud to attack with a fragmentation grenade. By dawn, Force X was digging in on the high ground beyond Gela preparing for the eventual counterattack.

It came about midmorning. As an Italian tank–infantry column came south on Highway 117 toward Gela, naval

gunfire stopped the infantry and hit several tanks, but about ten of them got into Gela. The rangers and 39th Engineers, reinforced by bazooka-firing engineers of the 531st Engineer Shore Regiment, disabled three tanks and the rest withdrew. Soon after this action, Italian infantry attacked from the northwest. As the Italians advanced in parade ground fashion, the rangers and engineers stopped them with heavy loses before they reached Gela.

By the evening of D-day, most beaches were secure, but there was a problem in the 1st Division area. The scattered paratroopers had not been able to secure the high ground. Fearing more counterattacks, Patton ordered ashore the Army reserve, the 2d Armored Division, plus the 18th Infantry Regiment.

The next morning, with only the infantry in place, and while the 531st Engineers struggled to move the Shermans across the soft beach sand, several Axis columns approached the 1st Division area. Naval gunfire hit a force of Italian infantry and German tanks advancing along Highway 117 toward Gela, forcing the tanks to swing toward the beach. With the infantry isolated and pinned down, five engineer half-tracks sallied forth from Gela and captured over 300 Italians.

As the tanks drove toward the beach, they were joined by a column of German infantry and Tiger tanks. By this time, the engineers had moved five Sherman tanks across the beach to join a defense line manned by direct firing artillery, infantry, and engineers from the 1st and 531st Engineers. As this line halted the German attack, Colonel Gavin's paratroopers, to include members of the 307th Airborne Engineer Battalion, hit them in the flank. By early afternoon, the Germans withdrew, leaving behind 16 tanks burning on the battlefield.

In the meantime back at Gela, another Italian infantry attack developed at noon. Force X, with the help of naval gunfire, stopped the attack short of the town, and again the engineers sallied forth in their half-tracks. This time over 400 Italians surrendered. That ended the counterattacks.

By 12 July, the American beaches were linked and secure, and contact had been made with the Eighth Army on the right. With the engineers repairing ports and airfields in all

division zones, Patton pushed forward. Aggressive by nature, he was not satisfied with the rather vague mission of protecting Montgomery's left flank as the Eighth Army drove up the east coast toward Messina. When Montgomery's advance pushed west of Mt. Etna, it forced Patton to sideslip the 45th Division to the left of the 1st Division. The Seventh Army was now oriented toward Palermo, and Patton had an objective worthy of his army.

On 17 July, General Alexander authorized a Seventh Army move toward Palermo and the north coast. Patton organized the offensive with Major General Geoffrey T. Keyes' Provisional Corps of the 3d Infantry and 82d Airborne Divisions on the left and the II Corps on the right. The 2d Armored Division was in Army reserve. The 1st Engineer Special Brigade became the Seventh Army Services of Supply (SOS) with an organization that included the 36th, 40th, and 540th Engineer Combat Regiments and the 531st Engineer Shore Regiment. It was responsible for all unloading over the beaches and through the ports and for supply forward. Colonel Davidson felt that an organization that had brought ashore over 66,000 men, about 18,000 tons of cargo, and more than 7,000 vehicles in the first three days of the campaign could support the drive to Palermo and the north coast.

The attack kicked off on 19 July. The Provisional Corps pushed through mountainous terrain where the roads were easily blocked and the villages were obstacles to advance. The division engineers paced the drive as there were no corps engineers at the start. Not until 20 July did the 20th Engineer Combat Regiment join the Provisional Corps.

Against little opposition, the 82d Airborne Division moved 25 miles in the first day. The 307th Airborne Engineers built a bypass around the demolished Platani River bridge, and the next day the division moved 20 miles. On 21 July, Darby's Force X, attached to the 82d, forded the Belice River. Then the 17th Armored Engineer Battalion, 2d Armored Division, emplaced a treadway bridge.

In the 3d Division area, over even more rugged terrain, Lieutenant Colonel Leonard L. Bingham's 10th Engineer Combat Battalion cleared roads, repaired bridges, and built bypasses to pace the drive. The 3d Division took Prizzi on 20 July; and by the evening of 22 July, it was on the

outskirts of Palermo. General Keyes accepted the surrender of the city that night.

Meanwhile, II Corps attacked toward the north on 19 July with the 45th Division on the left and the 1st Division on the right. On 21 July, the 1st Engineers repaired a bridge south of Petralia to continue the 1st Division drive. The division took Petralia on 23 July and then turned east on Highway 120. Meanwhile, the 45th Division reached the north coast at Termini on the same day and turned east on Highway 113.

On 23 July, General Alexander, realizing that the Eighth Army was not strong enough to take Messina, and with the Seventh Army already in position, ordered Patton to attack east on Montgomery's left. Assigned Highways 113 and 120, Patton had room for just II Corps. The coast road, Highway 113, ran along a narrow belt between the ridge noses and the beach. The inland road, Highway 120, ran along the southern slopes of the Caronie Mountains. It was narrow and crooked with steep grades and sharp turns.

Again, the engineers would pace the drive because the rate of advance depended on their ability to clear the roads to get the armor, artillery, and supply vehicles forward. Clearing the high ground covering the roads so engineers could open and maintain the axis of advance would not be easy against a determined enemy.

This time the defending force would be more tenacious than that faced in the drive on Palermo. General Hans Hube, commander of the XIV Panzer Corps, took over tactical control of the battle on 18 July. He kept the Hermann Goering Division in the south opposite the Eighth Army, but he assigned two divisions to the north opposite Patton. When the 29th Panzer Grenadier Division arrived on 19 July, Hube placed it in defense of Highway 113 and kept the 15th Panzer Grenadier Division along Highway 120. Hube ordered a defense built around a series of strong points, with withdrawal allowed only under overwhelming pressure.

To help provide that pressure, the 1st Engineer Special Brigade would initially have to move supplies across the beaches and through the minor ports at Gela, Licata, and Porto Empedocle. On 23 July, the 20th Engineers began repairing the Palermo port to accommodate 36 LSTs and

14 Liberty ships. By 28 July, the port was operating at 30 percent capacity. That figure improved throughout the campaign as eventually the 540th Engineer Combat Regiment, the 343d Engineer General Service Regiment, and the 1051st Engineer Port Construction and Repair Group all worked on the rehabilitation.

In addition to operating the ports and beaches, the 1st Engineer Special Brigade stocked and operated Seventh Army depots. In the process, the 696th Engineer Petroleum Distribution Company erected two 5,000-barrel storage tanks at Gela and by 21 July had a 4-inch pipeline through to the nearby airfield. By 26 July, a similar pipeline was in to Comiso airfield, and a storage facility was operational at Porto Empedocle.

In II Corps, the 39th Engineers had a battalion supporting each of the division engineer battalions. A battalion from the 19th Engineers soon joined the corps and eventually each attacking division had a corps engineer regiment in support. They improved bypasses and erected Bailey bridges. On 29 July, II Corps established a bridge dump at Nicosia and organized a Bailey bridge train with a platoon from the 19th Engineers using captured four-wheeled German trailers.

At the army level, the 20th Engineer Combat Regiment worked on Highway 113 while the 343d Engineer General Service Regiment operated on Highway 120. They used captured rollers, portable rockcrushers, and stockpiles of crushed stone and asphalt to maintain the roads, build culverts, and repair railway bridges. The 20th Engineers began repairing the rail line between Palermo and Santo Stefano on 30 July. They rebuilt four bridges, opened a tunnel, and replaced a considerable amount of track. The line opened on 9 August.

The Seventh Army's drive to the east and Messina began on 24 July. By the 28th, the 1st Division was in Nicosia after an advance of 15 miles. On 31 July, it took Ceramic, eight miles further along Highway 120. As the 9th Infantry Division was to replace the 1st Division on 1 August, General Allen used a 9th Division unit, the 39th Infantry Regiment, to push on toward Troina where the relief would take place. On 31 July and 1 August, the 39th used the direct approach east on Highway 120 and was stopped cold.

Troina was an ideal defensive position for the 15th Panzer Division. The highest town in Sicily, it sat atop a 3,600-foot mountain. The Germans blocked the approach roads by demolishing bridges and mining the bypass routes.

On 2 August, Allen, keeping the 1st Division in the fight, sent the 26th Infantry north of the town and the 16th Infantry across the virtually trackless, hilly terrain to the south. In support of the 16th Infantry, Company A, 1st Engineers bulldozed a road along the axis of advance. On 4 August, General Allen added another 9th Division unit to the battle when he sent the 60th Infantry Regiment wide around to the north. The division's 15th Engineer Combat Battalion, with the assistance of corps' angledozers and bulldozers, built a road across Monte Pelato toward Cesaro in support of the 60th Infantry move. In the face of this unrelenting pressure, the 15th Panzer Division withdrew from Troina the night of 5–6 August.

Meanwhile, in the north along Highway 113, the 45th Infantry Division had also started to push to the east on 24 July. By 31 July, they had advanced 15 miles to Santo Stefano against strong 29th Panzer Division defenses before the 3d Infantry Division replaced them. General Truscott's division reached a very strong defensive position along the San Fratello Ridge on 3 August. The Germans had blown the highway bridge over the Furiana River and mined the dry riverbed. They had also mined the 1½-mile stretch of land from the end of the ridge, across the road, to the water line.

On 4 August, Truscott pushed the 15th Infantry Regiment directly east along Highway 113 without success. At the same time, he sent the 10th Engineers to build a road up a mountain on the right so artillery could support an attack from that direction. The next day, while the 15th Infantry continued to attack unsuccessfully along Highway 113, the 30th Infantry Regiment had limited success moving across the hills on the right flank.

General Truscott then decided to try the left flank where he planned an amphibious attack for 7 August. A German air attack destroyed one of the LSTs, postponing the operation until 8 August. At 0315, a task force structured around Lieutenant Colonel Lyle A. Bernard's 2d Battalion, 30th

Infantry Regiment, landed in the vicinity of Sant' Agata, about five miles behind the San Fratello Ridge. In addition to his own battalion, Bernard had two batteries of self-propelled 105-mm. artillery, a platoon of five medium tanks, an engineer platoon from the 10th Engineers, and another engineer platoon from the 2d Battalion, 540th Engineers.

While the 540th Engineers used D-7 bulldozers to clear away beach obstacles, the 10th Engineer Platoon went forward with the tanks and artillery as Bernard positioned his task force to cut Highway 113 and block the withdrawal route of the 29th Panzer Division. But the 29th had already withdrawn, and by the time Bernard's force made contact with the 7th Infantry, only Italian rear guard troops were captured.

As the 3d Division continued east on Highway 113 on 8 August, the 9th Division entered Cesaro on Highway 120. The Germans had withdrawn to a defense line which ran from Cape Orlando in the north, through Randazzo in the center, to the southeast coast behind Mt. Etna. From there General Hube planned a three-phased withdrawal to Messina. It was an ideal situation as the retiring Germans required fewer and fewer troops to cover the decreasing terrain.

The 9th Division pushed east along Highway 120 toward Randazzo on 9 August. The Germans mined this area more heavily than any place in Sicily, and the metallic content of the soil rendered the SCR-625 minesweeper all but useless. Probing, although hazardous, nerve-wracking, and time-consuming, was the only solution. Company B, 15th Engineers, supported the 47th Infantry along Highway 120 as the rest of the battalion, plus corps engineers, built a parallel road north of the highway to support a flanking movement. The 9th Division took Randazzo on 13 August, and the Germans withdrew to their first evacuation phase line.

As the 9th Division was pushing toward Randazzo, the 3d Division continued to drive east along Highway 113. By 10 August, it was preparing to attack Naso Ridge, the northern end of the German defense line, which ran south through Randazzo.

With a situation similar to the San Fratello position, General Patton ordered another amphibious operation. General Truscott agreed, but he asked for a 24-hour delay as his division was not yet through Naso Ridge, and the

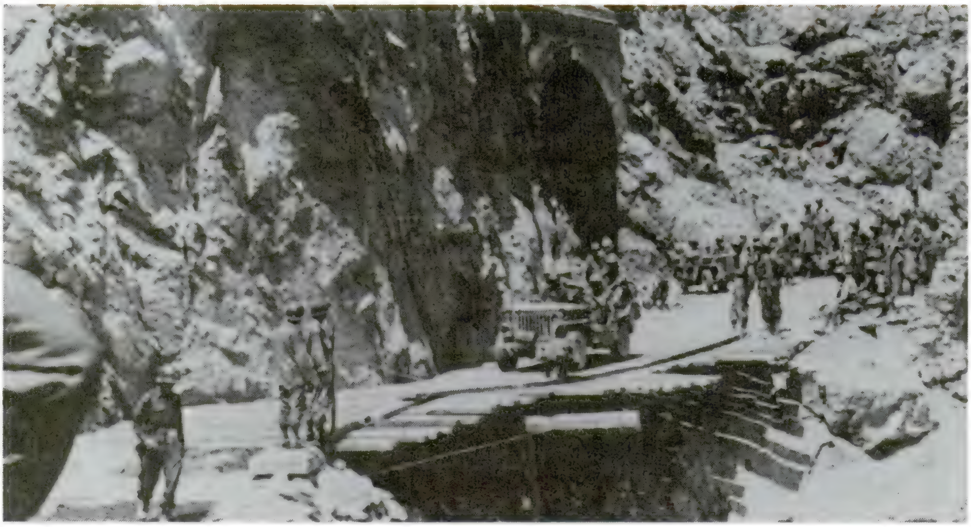
amphibious objective was 12 miles away. He was concerned that his land element would take too long to reach the amphibious task force and that the 29th Panzer Division could use the time to do considerable harm to the task force. Patton refused.

Thus, at 0243, 11 August, Colonel Bernard's task force, with the same organization as the previous operation, began to land on a beach near Brolo. His mission was to occupy the high ground of Monte Cipolla and position his force to control Highway 113. As the 540th Engineers cleared the beach, the 10th Engineers moved inland to help the artillery and armor into position on low ground along the highway. There was no German reaction, and by dawn, Bernard had the high ground and was in position to block the highway from both the east and west.

After repulsing an 0700 attack from the south, Colonel Bernard called on his offshore naval gunfire support to scatter a truck-borne infantry column, which came from the west about 0900. Thirty minutes later, Bernard's artillery halted a tank–infantry attack from the west. At midmorning, the cruiser, USS *Philadelphia,* and its six-destroyer escort returned to Palermo because there were no more targets.

But by this time, the 29th Panzer Division, knowing it was in trouble with a battalion-size force cutting its withdrawal route, began to react accordingly. At the same time, the 3d Division was still far from linkup with Colonel Bernard's force. The 71st Panzer Grenadier Regiment moved east from Naso Ridge to clear the division withdrawal route as a tank–infantry team assembled in Brolo for an attack west along the road. Bernard requested the Navy to return for gunfire support and asked the division for all the air and artillery support available.

It was not enough. The German armor got into Bernard's tanks, artillery, and engineers on the low ground, and at 1600, he ordered a withdrawal to the high ground for a last stand. By 1900, the Germans were in control of the highway, but they did not bother Bernard's force on Monte Cipolla because they were more concerned with retiring to their next defensive position. By the time the 3d Division reached Bernard's position at 0730 on 12 August, the 29th Panzer Division had withdrawn. All units in Bernard's task force, to include the



General Truscott takes the first vehicle across the bridge, 14 August 1943.

Grading closed two-thirds of the gap, but with no Baileys immediately available, the engineers used captured lumber to "hang a bridge in the sky." Starting at noon on 13 August, Company A, although able to position only one platoon at a time due to a lack of work space, completed the foundation by dawn 14 August and nailed the last floor plank down just before noon. General Truscott's jeep was the first vehicle across. The engineers then strengthened the bridge to allow heavier vehicles to cross. The official Army history termed the bridge construction "a landmark of American engineer support in Sicily."

Pushing on to the east, the 3d Division had patrols in Messina by the evening of 16 August. When General Patton accepted surrender of the city the next morning, organized resistance ended.

The Sicilian campaign was over, and the Allies had the southern gateway to the European continent. As General Truscott returned to Palermo from Messina in a three-hour jeep ride, he remembered it had taken his division 16 days to come the other way. It had been a grueling campaign for all concerned, to include the engineers.

General Eisenhower was lavish in his praise of engineer reconstruction of demolished roads and bridges, and clearing of minefields. General Patton said, "I believe that except for

the superior manner in which the engineers of all classes functioned, the outstanding success of the Seventh Army would have been impossible."

The engineers would have to apply what they learned in the next campaign, the thrust onto the Italian peninsula against a still determined German enemy.

Sources for Further Reading

The engineer story is found in Alfred M. Beck, *The Corps of Engineers: The War Against Germany, United States Army in World War II*. For the campaign, look to Albert N. Garland and Howard McGaw Smyth, *Sicily and the Surrender of Italy, United States Army in World War II.*

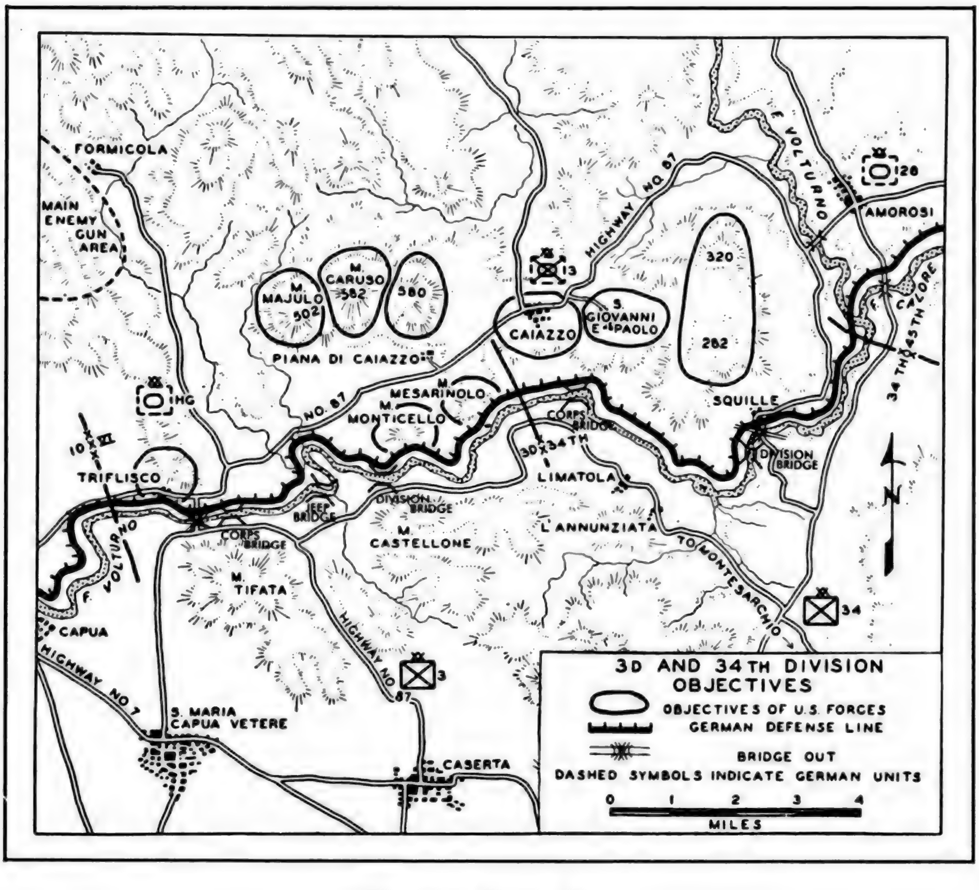
Individual engineer unit histories available include the 1st, 10th, 15th, and 120th Engineer Combat Battalions.

The Volturno River Crossing

by James W. Dunn

The seizure of Sicily in August 1943 provided the Allies several possible alternatives for future operations in the Mediterranean theater. They could attack into southern France or they could go farther east and invade the Balkans. A third possibility, and the one chosen, was to continue the advance north into the Italian peninsula. The attack, which would probably knock Italy out of the war, would gain airfields in the south of that country from which the Allies could attack Germany.

The Germans, realistic about the Italian situation, expected them to surrender if the Allies invaded. In that event,



Volturno River, Italy

they had a choice to make regarding future actions: they could defend all of Italy, withdraw completely, or defend in the north using the Apennines. Hitler initially opted to defend in the north; but his commander in southern Italy, Field Marshall Albert Kesselring, wanted to defend the whole country. He convinced Hitler to allow him to keep in southern Italy the troops withdrawn from Sicily. When they had more success than expected in defending against the Allied landing at Salerno, Hitler agreed to reinforce Kesselring and allow him to fight a campaign south of Rome.

General Dwight D. Eisenhower, Allied Mediterranean theater commander, felt that after Salerno, the Germans would withdraw north of Rome and that the Allies had to advance to at least Pisa to defend the southern airfields. Therefore, he ordered a fall 1943 campaign in the south of Italy, thereby setting the stage for an attack across the Volturno River—the first American attack of a defended river line in the war against Germany.

For the Germans fighting a delaying action, the terrain of southern Italy and the fall weather gave every advantage to the defense. The Volturno River, forming a continuous obstacle directly in the path of the American advance, was the first good defensive position north of Naples. The river was a particularly strong position to defend when heavy rains put it in flood; and, in the event, the rains in the fall of 1943 transformed the Volturno into a major obstacle. The Germans felt that the rain-swollen river would require the Americans to pause, bring forward bridging equipment, and prepare for a coordinated attack.

The Volturno River, where American forces approached in October 1943, was from 150 to 220 feet wide, from 3 to 5 feet deep, and fordable at some points. The fall rains made the current swift and dangerous. The banks, 5 to 15 feet high, were steep and rain slick and would hamper boat launchings. The high ground on the north shore gave the Germans excellent artillery positions and observation posts that would have to be eliminated before the engineers could attempt to emplace any vehicle bridges. Brush and olive groves on the north shore provided concealment for the defenders, while the open fields south of the river offered the attackers no covered approaches to crossing sites. Moreover, the south shore

road net was inadequate for rapid movements of large bodies of men and equipment. In addition to swelling the river, the fall rains turned the roads into muddy quagmires.

As the Germans withdrew north, they destroyed all bridges along those roads capable of handling military traffic. Indications of a stiffening German resistance included air photos of the Volturno River line which showed Monticello and Monte Mesarinolo on the north shore fortified for a strong defense. American patrols reaching out towards the river found German patrols active on the south bank but managed to determine that the river line defense included minefields, machine gun nests, and observed artillery fire.

The German forces providing the defense were from the Tenth Army commanded by General Heinrich von Vietinghoff. He gave the XIV Panzer Corps responsibility for the Volturno River line. The corps included the Hermann Goering Division of four infantry battalions, an armored force, and a large number of motorized assault guns. The other division in the corps defense was the 3d Panzer Grenadier Division with an attached reconnaissance battalion from the 26th Panzer Division.

The Germans laid extensive minefields, organized a system of machine gun nests sited to cover the riverbank with interlocking bands of fire, and zeroed in artillery on the most likely bridging sites. They then waited in the heights overlooking the swollen, racing Volturno River, prepared to repel any crossing attempt.

The American forces which approached from the south were from Lieutenant General Mark W. Clark's Fifth Army. Clark chose the VI Corps, commanded by Major General John P. Lucas, to make the crossing. From his corps, Lucas decided to use the 3d Infantry Division commanded by Major General Lucian K. Truscott, Jr., and the 34th Infantry Division under Major General Charles W. Ryder. Engineer support for the crossing included the two divisional battalions, the 10th Engineer Combat Battalion of the 3d Division and the 109th Engineer Combat Battalion of the 34th Division. Corps engineer support came from the 16th Armored Engineer Battalion and the 36th and 39th Engineer Combat Regiments. Weather, the terrain, and German defensive tactics would combine to test the river-crossing capability of these American engineer units.

Kesselring ordered Vietinghoff to contest every foot of territory and hold the Volturno line until at least 15 October to provide time for construction of the main defense line south of Rome. Supported by the bad weather and good defensive terrain, Vietinghoff used delaying tactics to slow the American advance from the south. In the time gained, he reinforced his defenses along the Volturno River.

For the Fifth Army, speed was essential to deny the Germans time to build up their defenses along the river. However, Clark's hope for a rapid crossing of the river by 6 October foundered on the severity of the fall rains and the quality of the German defensive tactics. It was not until 9 October that he could order Lucas to conduct a corps attack across the Volturno. Again, the weather and German delaying actions intervened, and Lucas did not have his two divisions on line and ready to attack until 12 October.

As all hope for a quick jump across the Volturno vanished, Lucas planned a coordinated attack against a fortified river line. Along a 15-mile front between Capua and the junction of the Calore and Volturno rivers, he prepared a two-division attack with the 3d Division on the left as the main attack and the 34th Division on the right as the supporting attack.

General Truscott planned a feint opposite the Triflisco Gap on the left of his 7-mile 3d Division front. He felt the Germans expected the main attack there because that area had good roads and a narrow river course. Rather, he planned his main attack in the center of the line with a supporting attack on the right. The division's initial objective, needed to facilitate early bridge construction, was the high ground north of the river. Truscott was concerned about getting armor, artillery, and heavy equipment across the river to support the infantry; so he wanted the bridges in as soon as possible.

There were three bridges planned for the 3d Division area. In the Triflisco Gap on the left, the 16th Armored Engineer Battalion (−), supported by the 39th Engineer Combat Regiment, was to build a 30-ton treadway corps bridge while in the center, Company A, 10th Engineer Combat Battalion, built a light jeep bridge and Company B of the same battalion built an 8-ton division bridge capable of carrying 2 1/2-ton trucks. Truscott wanted the jeep bridge in first to

get light equipment across the river early in the operation. Next in priority was the division bridge to carry artillery, and last was the corps bridge for armor and heavy equipment.

In the 34th Division area, General Ryder planned an attack of two regiments abreast along his 8-mile front to seize the high ground quickly and deny the Germans the chance to direct observed artillery fire on the bridge sites. Company B, 16th Armored Engineer Battalion, and the division engineers were to build the corps bridge, a 30-ton treadway, on the left; while on the right, the 36th Engineer Combat Regiment, with division engineer help, built the 8-ton division bridge.

In both division areas, engineer assistance to the infantry was critical. By guiding them down the riverbanks and across the fords and operating the assault boats, the engineers would play a crucial role in the attack across the Volturno River.

The 3d Infantry Division reached the south bank of the Volturno on 6 October, and on 8 October, the 34th Division began moving toward the river. Engineer patrols determined that all bridges across the river were down, but despite the river's depth and swift current, tank and infantry fords were available. The patrols came under German machine gun fire along the riverbank and saw artillery fire hit expected crossing sites. Their reconnaissance proved that the Germans were waiting in the hills overlooking the Volturno, prepared to defend the river line.

To assist the assault troops, the engineers brought forward guide ropes and 1,000 kapok life jackets they found in a Naples warehouse. Because there were not enough assault boats, they improvised, borrowing rubber boats from the Navy, preparing 6-ton pneumatic floats for use as assault boats, and building rafts out of old water cans and oil drums. In the rear, they built and improved river approach roads and practiced bridge construction. Then they waited.

The 3d Infantry Division began the feint in the Triflisco Gap at midnight, 12 October. Two hours later, the division's 7th Infantry Regiment went forward in the main attack. Supported by the division's 10th Engineer Combat Battalion and engineers of the 1st Battalion, 39th Engineer Combat Regiment, the assault force battled both the swift current

and the German machine guns. Some troops waded the river with the aid of guide ropes while others crossed in the improvised assault boats. Guide ropes broke loose from anchors and boats broke up in the swift current as the German machine gun fire whipped the water surface. The crossing went slowly, and it was dawn before the assault battalion had crossed. Two reserve battalions quickly followed, and by 0800, the 7th Infantry reached the base of its main objective, Monte Majulo.

On the right of the division line in the supporting attack area, the 15th Infantry Regiment faced similar problems with the current and the German defenses; but by dawn, that assault force was also across the river. In the early morning hours, the regiment drove toward the high ground which dominated the site chosen for the division bridge.

With the main and supporting attacks succeeding, Truscott ordered the 30th Infantry Regiment to turn the Triflisco Gap feint into an assault across the river. The regiment made two attempts; but the Germans, knowing the value of the crossing site, reacted fiercely and repelled both attacks. A British 56th Division company-size attack in the X Corps area on the left of the 3d Division was supposed to assist the Americans, but the Germans beat it back as well. By the end of 13 October, the Germans continued to hold Triflisco Gap, thereby preventing construction of the corps bridge.

In the 34th Division area, General Ryder sent two of his regiments, the 168th Infantry on the left and the 135th Infantry on the right, across the Volturno River at 0145, 13 October. The division's 109th Engineer Combat Battalion supported the crossing as slippery and steep riverbanks and German machine gun fire made it difficult for the attack force. The swift current prevented the engineers from returning some assault boats to the south shore, so many in the following waves had to cross through chest-high water. It took five hours for the assault battalions to complete the crossing, but by dawn, the engineers were able to begin operating a light vehicle ferry in the 135th Infantry area.

At the same time, even though the Germans still held the high ground and thus could bring observed artillery fire on the bridge sites, the engineers were ordered to

begin construction of the division bridge near the town of L'Annuziata in the 168th Infantry area. To save time and eliminate the noise of an air compressor, Company A, 36th Engineer Combat Regiment, inflated the 6-ton floats and attached the saddles before loading their trucks. The company operated by platoon with the first off-loading, while the second carried the equipment to the river, where the third assembled and launched the bridge.

As the company approached L'Annuziata, German artillery fire disabled three trucks and damaged several floats. The engineers pushed on and had three floats in the water when the German artillery fire increased, destroying the launched floats and driving the engineers back from the river. As bridge construction was impossible under the accurate artillery fire, the engineers withdrew to a defiladed position behind the town. Later that day, they tried again under the cover of a smoke screen, but the smoke drew fire, and once again the engineers withdrew from the division bridge site.

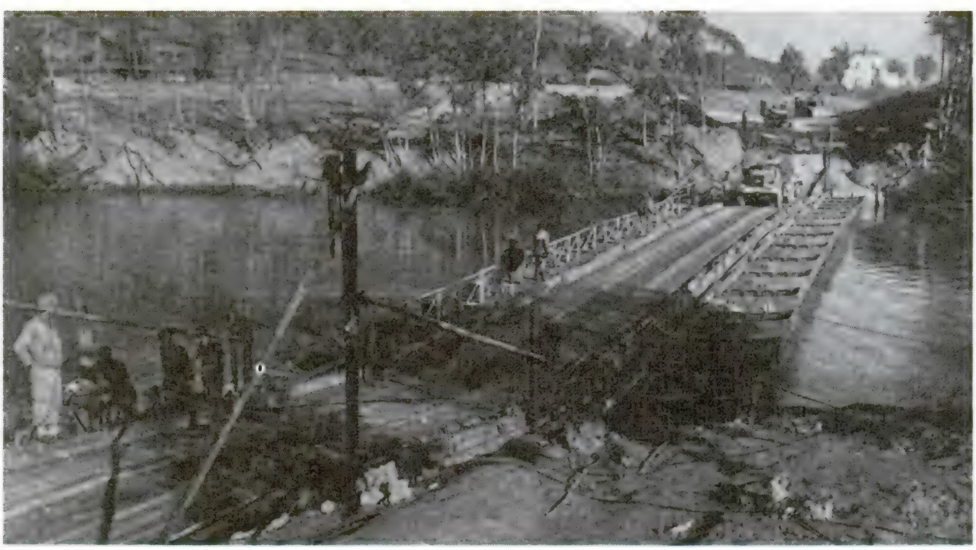
Throughout 13 October, the Germans directed artillery fire onto all potential bridge sites in the 34th Division area. In those conditions, Company B, 16th Armored Engineer Battalion, found it impossible to begin construction of the corps 30-ton treadway bridge. Something would have to be done about the observed artillery fire before bridge construction could begin.

Meanwhile, the 3d Division continued to reinforce its assault battalions north of the river. Shortly after dawn, at a ford in the 7th Infantry area, engineers using bulldozers began construction of a tank approach route; but German artillery fire caused heavy casualties among the operators, stopping the work. At the same time, General Truscott learned that German tanks were advancing on the infantry north of the river. On his way to the river, he encountered engineers moving toward the division bridge site; and he told them of the dire need for engineers, using picks and shovels under artillery fire, to level the riverbank at the tank ford so American armor could cross and assist the infantry. He said their response was immediate and inspiring as they double-timed toward the riverbank. By noon, 15 tanks and 3 tank destroyers were across the tank ford and moving to the aid of the riflemen.

As the fighting raged along the river throughout the morning of 13 October, Company A, 10th Engineer Combat Battalion, worked on the jeep bridge in the 7th Infantry area. The bridge they built was a marvel of battlefield innovation. Lacking standard equipment, they used Italian railroad track, steel runway matting, and heavy floats borrowed from the 16th Armored Engineers to build an unorthodox, but useful, light vehicle bridge. It was operational by the afternoon.

In the 15th Infantry area, Company B, 10th Engineers, was having a more difficult time with the division 8-ton pneumatic float bridge. Accurate German artillery fire damaged several floats and finally forced the engineers to halt work on the bridge. When General Truscott visited the site soon thereafter, he told them how vital the bridge was to the success of the crossing. He said they went back to work as nonchalantly as though at a demonstration. They completed construction of the bridge by midafternoon.

Failure to take the Triflisco Gap on 13 October prevented construction of the corps bridge. So, while there were two bridges operational in the 3d Division area, neither was capable of carrying armor and heavy equipment. As the 30th Infantry could not force the gap directly, Truscott sent them upstream to use the jeep bridge and flank the German high ground position. This they did after dark on 13 October, and by the morning, Triflisco Gap belonged to the 3d Division.



The corps bridge at Triflisco Gap, Italy.

The 16th Armored Engineers then began construction of the corps 30-ton treadway bridge while engineers from the 10th Battalion and the 39th Regiment prepared approach roads. German artillery fire from the British sector hampered the work, but by early afternoon, 14 October, the corps bridge was in. The bridges in the 3d Division area could now carry vehicles from a jeep to a medium tank across the Volturno River.

Fixed bridge at Capua, Italy. When the Germans retreated across the Volturno River, they destroyed every bridge in the path of the Allied advance.

Meanwhile, the engineers in the 34th Division area found a solution of sorts to the accurate German artillery fire. Prevented by the shelling on 13 October from constructing any bridges, they knew they had to emplace at least one on the 14th or the river crossing could fail. Company A, 36th Engineer Combat Regiment, found a defiladed location near the village of Squille, upstream from the original division bridge site. At this new site, the river was 70 feet wider; and that additional width, plus the earlier loss of equipment, required the use of 12-ton floats together with the 6-ton floats. A hinge at the junction of the two different-sized floats made by using one instead of two pins allowed the combination. The bridge was ready by midmorning on 14 October.

The completion of the division bridge solved some of the supply problems for the 34th Division; but until the engineers could build the corps 30-ton treadway bridge, exploitation of the river crossing would be impossible. Through the morning of 14 October, the Germans continued to direct artillery fire onto the corps bridge site from the high ground around the village of Caiazzo. As the 168th Infantry pushed forward, the Germans resisted stubbornly. They knew that once they lost the high ground, a major bridge would be built, allowing the Americans to push heavy equipment across the river. By mid-afternoon, the 168th forced the Germans off the high ground and that evening took Caiazzo. Immediately, Company B, 16th Armored Engineer Battalion, began construction of the corps bridge. With its completion by midnight, the 34th Division began to pour men and supplies across the Volturno.

A wrecked ponton bridge washed out by flood waters on the northern Volturno River.

On 15 October, the two American divisions broke out of their bridgehead north of the river and began to pursue the Germans as they withdrew to their next defensive position south of Rome. The engineers constructed additional bridges across the Volturno to support the push north.

As the Allies moved toward Germany, there would be many more rivers to cross and bridges for the U.S. Army

The 16th Engineer Battalion adds steel sections to protect a ponton bridge against the rising waters of the northern Volturno River.

Engineers to build. Ahead lay the Rapido and Po in Italy and the Seine and the Rhine in northern Europe. Some would be easier than the Volturno, but many would be harder. Engineers undertaking the subsequent crossings could and did learn from the first contested American river crossing of the European war—the fight at the Volturno River in October 1943.

Sources for Further Reading

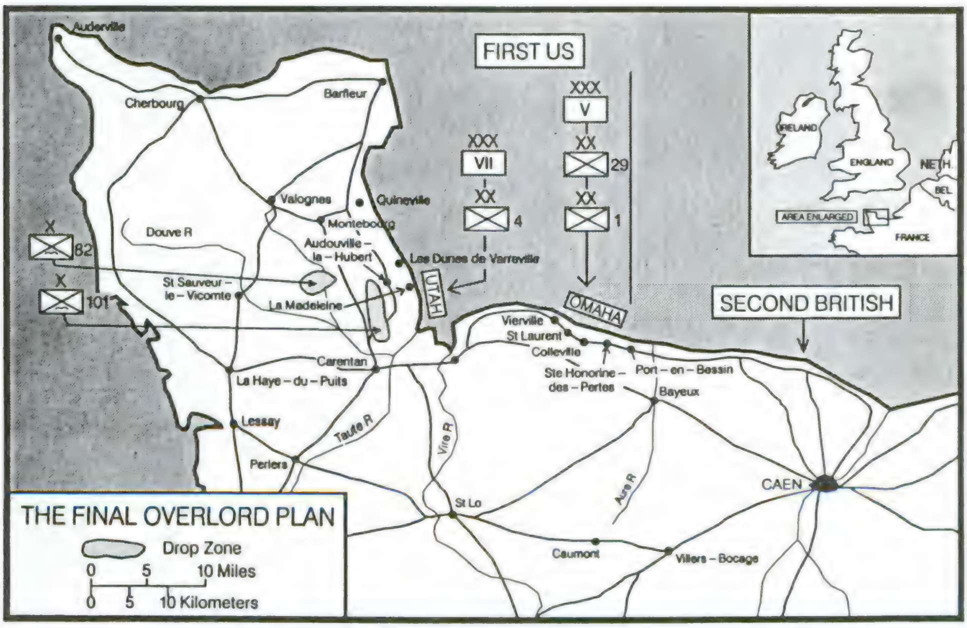
The engineer story is found in Alfred M. Beck, *The Corps of Engineers: The War Against Germany, United States Army in World War II.* For the campaign, look to Martin Blumenson, *Salerno to Cassino, United States Army in World War II.*

A division commander's view is available in Lieutenant General Lucian K. Truscott, Jr., *Command Missions*, while the small unit level is seen in *From Volturno to the Winter Line*, American Forces in Action Series.

The Normandy Landing

Barry W. Fowle

On 6 June 1944, the Allies began Operation OVERLORD, the invasion of the European continent that was designed to bring to a close a war that had lasted far too long. The amphibious assault on Normandy in World War II was the key to the continent. Two years of planning went into Operation NEPTUNE, as the landing on Normandy was known. The troops would assault in five beach areas with an initial strength of six reinforced infantry divisions landing from the sea and three airborne divisions dropping behind the lines by parachute and glider. The First United States Army would land on two beaches, and the Second British Army would land on three beaches.



Final Overlord Plan

The planners chose First Army to make the D-day assault for the Americans on two beaches, OMAHA and UTAH. They assigned OMAHA Beach to V Corps, with its 1st and 29th Infantry Divisions. VII Corps got UTAH Beach. Its 82d and

101st Airborne Divisions would drop inland and link up with the 4th Division landing on the beach several hours later.

The Engineer Special Brigade Group (Provisional), consisting of the 5th and 6th Engineer Special Brigades (ESBs), provided landing support for V Corps. On D-day it landed 34,250 men and 2,870 vehicles. Of these, 5,632 men and 315 vehicles belonged to the Engineer Special Brigade Group. Approximately 2,500 other engineers—members of corps and divisional units—also landed. Engineers made up approximately 25 percent of all the troops that landed on OMAHA.

Thirty engineer officers and 516 engineer enlisted men, to include 11 officers and 115 enlisted men who were Navy demolitions personnel, landed with the 1,450 assault infantry during the first phase of the operation. Of the personnel that made the initial landings at 0630 hours on 6 June 1944, engineers represented over one-third.

The 1st Engineer Special Brigade (ESB) conducted similar operations on the American UTAH Beach where, on the first day of the invasion, it put ashore some 20,000 troops and 1,700 vehicles of VII Corps' 4th Infantry Division and supported units.

Assault gapping teams designed to blow holes in the obstacle lines on the beach, called Assault Force O (OMAHA) and Assault Force U (UTAH), trained at the British Assault Training Center, Woolacombe, England. Intelligence provided aerial photographs showing types of obstacles on OMAHA Beach, and mockups were made of these for training purposes. The men completed schooling in four weeks.

OMAHA Beach was a 7,000-yard slash of sand with up to 200 feet exposed at high tide and as much as 400 yards showing at low tide. An 8-foot bank of coarse shingle (gravel) marked the seaward edge of the western part of the beach. To the rear of the center of the beach, a line of grass-covered bluffs rose some 100 to 170 feet. They sloped downward at either end, merging with the rocky coast that enclosed OMAHA.

Generally, the obstacles on OMAHA consisted of two bands, 50 to 75 yards wide, with about the same distance separating them. The outer line of obstacles consisted of: element C (Belgian Gate) with a specially adapted waterproofed version of the German, powerfully lethal, antitank

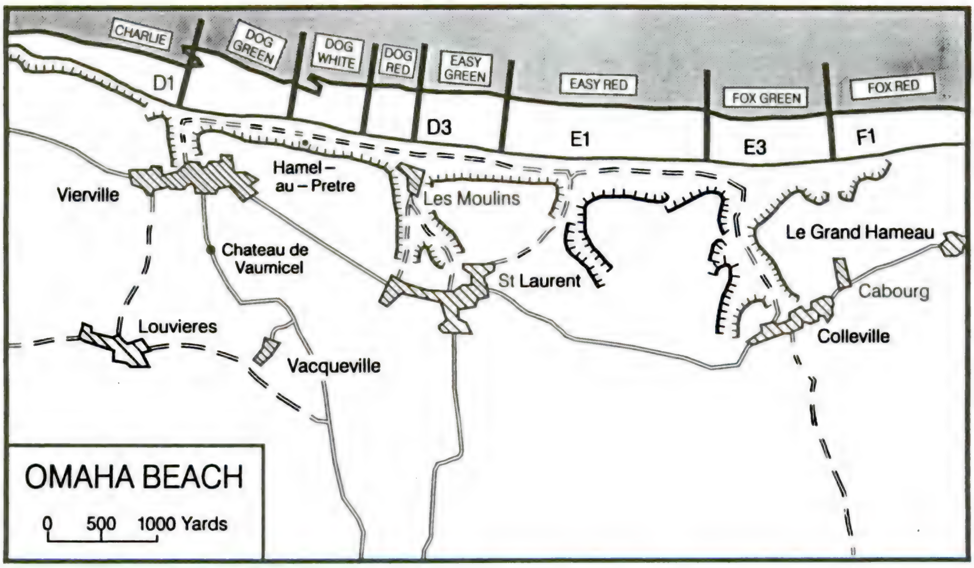
Model of a Belgian Gate, part of the engineer demolition range at the U.S. Assault Training Center, 11 February 1944.

Teller mine on the forward face; wooden ramps; and posts topped with Teller mines. The inner band combined wooden posts and ramp-style obstacles backed by three staggered rows of steel hedgehogs. The Germans spaced the element C, ramp-type, and post-type obstacles 20 to 40 feet apart and scattered them in depth. They spaced the steel hedgehogs 10 to 15 feet apart.

Teller mine on a pole, UTAH Beach, France, 15 September 1944.

The general plan for the engineers called for the progressive development of the OMAHA beachhead in three phases: the assault phase, the initial dump phase, and the beach maintenance dump phase. The first two phases took place on D-day. During the assault phase, engineer special assault gapping teams, support teams, and command teams came ashore and destroyed the obstacles lining the shore. Engineer battalion beach groups followed these engineer

teams and established initial dumps of ammunition and fuel, cleared the exits, and developed roads for the supported infantry units. The assault planners divided OMAHA Beach into eight contiguous landing beaches with five designated exits leading through natural draws.



OMAHA Beach

Engineer assault, support, and command teams were alike in composition, but the assault teams carried fewer demolitions. Each team consisted of 28 Army engineers and a Naval Combat Demolition Unit (NCDU). The NCDU consisted of a naval officer and 12 enlisted men, 7 from the Navy and 5 (volunteers) from the Army. The teams carried 1,000 pounds of explosives, demolition accessories, mine detectors, mine gap markers, and other materials. Each member lugged 75 pounds of equipment, including 40 pounds of explosives. Sixteen assault teams went in with the infantry in the first wave to blow 50-yard gaps in the obstacles on the first tide, the Navy units working on the seaward band of obstacles and the Army units clearing the inshore obstacles. The support teams followed up within eight minutes, enlarging the gaps on the beach and destroying obstacles.

The 299th Engineer Combat Battalion (less one company at UTAH Beach) and ten NCDUs accompanied the 16th Infantry landing on the eastern sector of OMAHA. The 299th was the only American unit to land at both OMAHA and

the obstacles and refused to move. Wood then moved his men forward to support the infantry.

Other engineer assault teams had little more success. Team 13 lost its naval detachment when an artillery shell hit its boatload of explosives at Easy Red. The rest of the team could not set off its charges on the obstacles because infantry landing parties used them for cover. Team 12 cleared a 30-yard gap on Easy Red, but lost 19 men when a German mortar shell struck a line of primacord, prematurely setting off the charges strung about one series of obstacles. Team 11 arrived on the far left bank of Easy Red ahead of the infantry and lost over half of its men to enemy fire. A faulty fuse prevented the remainder of the team from blowing a passage through the obstacles.

Only two teams, 9 and 10, accomplished their missions on the eastern sector of OMAHA. Team 9 landed in the middle of Easy Red well ahead of the infantry waves and opened a 50-yard path for the main assault. Despite heavy casualties, Team 10, within 20 minutes of landing, cleared the infantry from behind the obstacles and demolished enough barriers to create gaps 10 to 50 yards wide.

The rest of the teams in the area fared about as well as Lieutenant Wood's team. At Fox Green, Team 16 plunged off its landing craft, mechanized (LCM) at 0633. Here too the infantry refused to leave the protective cover of the obstacles.

Team 15 lost several men to machine gun fire before landing at 0640 hours. It took more casualties when a shell hit its explosive-laden rubber boat. The survivors attacked the Belgian Gates farthest from shore, but heavy enemy fire cut away fuses as rapidly as the engineers could rig them. One burst of fragments carried away a fuseman's mechanism, along with all of his fingers. The team had no choice but to run for the protective low shingle bank on shore. Only 4 of the original 40-man team remained uninjured.

Seven teams bound for the 116th Infantry's beaches on the western half of OMAHA—Dog Green, Dog White, Dog Red, and Easy Green—were on schedule, most coming in ahead of the infantry companies in the first waves. The eighth team landed more than an hour late, its landing craft, tank (LCT) having sunk shortly after leaving England. The duplex-drive tanks, used as artillery on the 116th Infantry's beaches, could not match the German guns.

Team 8 landed a little to the left of Dog Green and blew a 50-yard gap in the barrier line before the infantry landed. Teams 3 and 4 were badly shot up and accomplished little. Teams 5 and 7 could not do a thing because the infantry took cover among the beach obstacles. Teams 1 and 6 managed to open 50-yard gaps, one on Dog White and the other on Dog Green.

Eight support teams and two command teams, scheduled to arrive within eight minutes, arrived late, between 0640 and 0745, and off course near Fox Red. Command Boat 1 unloaded a crew on the beach flat of Easy Green at 0645 and opened a 50-yard gap in the obstacles. Team D opened a gap of 30 yards, but the rest of the teams accomplished little else. German artillery put two rounds into Team F's LCM, wounding and killing 15 men. Only 4 men of the original team got to shore.

Of the 16 M4 tank dozers scheduled to land with the assault gapping teams, only 6 got ashore. With the beach so crowded, the engineers defused the mines on obstacles instead of blowing them. They then used the tank dozers to shove the barriers aside. Eventually the Germans knocked out all but 1 of the dozers.

The second phase of engineer operations on OMAHA began with the arrival of the four beach groups charged with providing overall control to engineer operations on the beaches: the 37th Engineer Battalion Beach Group, the 149th Beach Group with the 112th and 147th Engineer Combat Battalions (ECB), and the 348th Beach Group. The 336th Engineer Combat Group was scheduled to arrive in the afternoon and organize Fox Red.

The first landings of the engineer groups began with Captain Louis J. Drnovich, commanding officer of Company A, 37th ECB, who arrived at 0700 hours on Fox Green opposite Exit 3, 10 minutes ahead of schedule. Within the next 20 minutes, three other detachments of the battalion came ashore. Enemy fire still swept the beach, so these men assisted in aiding the wounded and in building up the fire line from the protection of the shingle instead of performing their engineer mission. At Exit E-1, one of two landing craft, infantry (LCIs) carrying the battalion staff broached on a stake and had to drop the men off into neck-deep water. They

waded ashore under machine gun fire to a beach still crowded with the men of the first waves. A mortar round killed the commander of the 37th, Lieutenant Colonel Lionel F. Smith, and two members of his staff, Captains Paul F. Harkleroad and Allen H. Cox, Jr., as soon as they landed. An LCI put Company B, 37th ECB, ashore safely at 0730 hours at Exit E-1, but Company A, scheduled to open Exit E-3 for the 3d Battalion, did not arrive until 0930. It had landed near E-1 and had to make its way east through the wreckage on the beach to E-3 where it ran into such heavy fire that it did little all day. Company C lost many men when it took a direct hit to its LCI on landing at Exit E-1.

Farther west, a 28-man reconnaissance and beach-marking team of Company C, 149th ECB, in support of the 116th Infantry, arrived at 0705 hours, five minutes early. It landed on Easy Green rather than the assigned Dog Red just to the west. The rest of the company arrived in LCTs at 0720 hours and moved forward to the shingle line while under fire from the hill behind the beach. Even though they were on the wrong beach, the men began cutting an access road through the dune line to the beach's lateral road. But heavy fire forced them back to the beach.

After landing on a beach in France, engineers lay out roads on the soft sands for the heavy vehicles and equipment yet to come ashore, 6 June 1944.

Still farther west, the first wave of the 147th ECB, 90 men of Companies B and C, reached Dog White at 0710. Artillery set the 147th's landing vessel afire and caused 45 casualties. The engineers left the boat in neck-deep water, abandoning their carry-off equipment.

The confusion of the first hour of the invasion mounted during the next. Landings continued, but men and vehicles could not move off the beach. Divisional and group engineers

Carrying full equipment, American assault troops move onto OMAHA Beach on the northern coast of France, 6 June 1944.

blew gaps here and there in the barbed wire along the dunes, and a few small infantry detachments managed to work their way toward the base of the slopes, but most of the units piled up behind the shingle bank in rows three deep. In many cases, the officers of these units had been killed or wounded. The rest of the 37th ECB landed in several groups near Exit E-1. Artillery fire twice drove away from shore the craft carrying the mine removal platoon of Company B. It was finally hit and beached. An 88-mm. shell destroyed the steering gear of the LCT bearing the reconnaissance group of Company C, forcing it to make an emergency landing. Units of the 348th ECB landed near E-1 instead of on Fox Beach as planned.

Obstacles on Easy Red forced LCI 92, with units of the 147th and 149th, to move to Dog White where it tried to force its way ashore. A mine set it afire causing heavy casualties. The survivors jumped into neck-deep water and made their way to shore. Many suffered from burns, shock, and exposure.

Slowly, against stiff German opposition, the Americans began opening the exits. At Exit E-1, where Lieutenant Colonel William B. Gara's 1st ECB and the attached 20th ECB worked on clearing a road off the beach, Sergeant Zolton Simon, Company C, 37th ECB, led his five-man squad in clearing and marking a narrow path through the mines. Wounded once while sweeping for mines, Simon got a second more serious wound after reaching the top of the bluff, but a path had been cleared. For his actions, he was awarded the Silver Star. Exposed to enemy fire, First Lieutenant Charles Peckham of Company B stood in the path and urged the infantrymen to follow Simon up the now mine-free trail. He received the Bronze Star.

To exploit the initial success at E-1, the engineers had to expand the exit lanes quickly. Mines, barbed wire, obstacles, antitank ditches, and impassable gravel and sand barred the tanks from moving until Private Vinton Dove, a bulldozer operator from Company C, assisted by his relief operator, Private William J. Shoemaker, took on these obstacles. Dove and Shoemaker cleared a road through the shingle, removed a roadblock at E-1, and filled the antitank ditch, opening a path for the Sherman tanks. For their actions, both men received the Distinguished Service Cross (DSC).

First Lieutenant Robert P. Ross, Company C, won the third of the three DSCs awarded to men of the 37th on D-day. Heavy fire from a hill overlooking Exit E-1 held up the advance so Lieutenant Ross added a leaderless company of infantry to his own engineer platoon and fought his way up the bluff. Ross's mixed command killed 40 Germans and captured two machine gun positions. Largely due to the efforts of men like Simon, Peckham, Dove, Shoemaker, and Ross, E-1 was cleared by noon on D-day and became the main egress from OMAHA Beach for the 1st Infantry Division.

Exit E-3 yielded slowly to engineer persistence. Still under artillery fire around 1630 hours, the beach remained unmarked for incoming boat traffic. As soon as engineers erected

of its equipment during the day, the 112th was unable to open Exit D-3 until 2000 hours.

Colonel Paul W. Thompson of the 6th ESB came ashore at Dog Green about 0730 hours on D-day. His subordinate units were attached to the 5th ESB the first day, so he assisted on the beach. About 1100 hours, while pushing a bangalore torpedo under a wire barrier during an assault on a beach bunker at Exit D-1, he was shot and seriously wounded. For his actions that day, Colonel Thompson was awarded the DSC.

The task of opening Exit F-1 belonged to the 336th Engineer Battalion Beach Group, scheduled to land after 1200 hours on D-day at Easy Red near E-3, then march east across Fox Green to Fox Red. Some of the advance elements went ashore on E-3 at 1315 hours and made their way through the wreckage on the beach, falling when enemy fire came in and running during the lulls.

Three platoons of the 336th's Company C landed at the end of OMAHA farthest away from the Fox beaches at Dog Green about 1500 hours. The men assembled at the shingle bank and began a hazardous march toward Fox Red, more than 2 miles away. By the time the engineer column reached the F-1 area at 1700 hours, 2 men had been killed and 27 wounded.

Once at Fox Red, the engineers turned to mine clearance. The men assembled several mine detectors from abandoned equipment and cleared the mines from fields near the beach. A tank dozer filled in an antitank ditch, and the teams worked up a hill with a tractor following, opening Exit F-1. By 2230 hours, 15 tanks had passed through the exit to the Colleville area to help the infantry clear the town.

Shortly after 1500 hours, Brigadier General William M. Hoge, Commanding General, Engineer Special Brigade Group (Provisional), landed at Exit E-1 and set up his command post in a concrete pillbox just west of the exit. From there, he assumed engineer command responsibility on OMAHA Beach, taking over from the 5th ESB commander, Colonel Doswell Gullatt.

To the west of OMAHA Beach lay the 9,000-yard-long UTAH Beach, extending from the mouth of the Vire River north–northwest to Quineville. Corps divided UTAH Beach into two beaches, Tare Green and Uncle Red, with four

exits. Longer and wider than OMAHA, UTAH lacked the commanding heights that gave the enemy at OMAHA a superior defensive position.

A masonry wall paralleled the beach. Behind it, the dunes leveled out into fields. Beyond the dunes, a water barrier ran a mile or so inland from Quineville on the north to Pouppeville on the south. The Germans had created the barrier by reversing the action of the locks constructed by the French to convert salt marshes into pastureland.

UTAH Beach

Seven causeways crossed the wet area in the region of the UTAH landings to connect the beach with a north–south inland road. Most were under water. The northernmost, although dry, could not be used because it was too close to German artillery. The assault area lay between two towns, La Madeleine on the south and Les Dunes de Varreville on the north. The southernmost beach on UTAH, Uncle Red, was 1,000 yards long and straddled a causeway road named Exit 3, which led directly to the village of Audouville-la-Hubert 3 miles behind the beach. Tare Green Beach occupied the 1,000 yards to the right of Uncle Red.

The density of obstacles encountered on UTAH Beach varied from moderate on the right flank to negligible on the left. The obstacles consisted largely of scattered wooden ramps shaped like the letter "A," element C, wooden and concrete piles, and tetrahedra or hedgehogs—about 5½ feet high and made of three or more steel rails or angles crossed at the centers, and so strongly set that the ends would cave in the bottoms of landing craft. Delay mines, conspicuously absent in the actual assault area, dotted the intended assault area.

VII Corps got the assault mission at UTAH. Plans called for the 8th Infantry Regiment, 4th Infantry Division, to go ashore, two battalion landing teams abreast, closely followed

by the 70th Tank Battalion as artillery support. They would work their way inland and make contact with the 82d and 101st Airborne Divisions, landing by both parachute and glider in the area behind UTAH Beach.

UTAH Beach plans called for the Ninth United States Air Force to bomb four paths through the beach obstacles just before H-hour, with fire lifting at H minus five minutes. The assault teams of the 1st ESB, Assault Force U, were to land immediately behind the 4th Division in the first wave to enlarge the paths opened by the planes and cut other gaps at 50-yard intervals.

Survivors of a landing craft sunk by enemy action off the coast of France used a life raft to reach UTAH Beach near Cherbourg.

The 1st ESB, supporting the landings of the 4th Infantry Division, VII Corps, on UTAH Beach, had duties similar to those of the 5th ESB on OMAHA. A battalion beach group of the brigade's 531st Engineer Shore Regiment operated Uncle Red Beach on the left and Tare Green Beach on the right. As soon as a third beach group landed, it would open a third beach, Sugar Red, to the right of Tare Green.

Plans called for engineer demolitions to begin at 0635 hours, five minutes after the infantry landed. Major Herschel E. Linn, who commanded the 237th ECB, led an ad hoc beach obstacle demolition party which controlled the teams. Linn planned eight 50-yard gaps, four in each of

the two landing sectors, Uncle Red and Tare Green. Twelve NCDUs would attack the seaward band of obstacles. Simultaneously, eight Army assault gapping teams would attack the landward obstacles.

Because of the smoke from the prelanding bombardment and the loss of two small Navy control vessels marking the line of departure off the beach, the entire first wave of the 8th Infantry's assault landed 2,000 yards south of its intended landfall. There they encountered light opposing fire and few obstacles. Within five to eight minutes, the teams blew the first gaps of more than 50 yards. The assault teams immediately wired and blew their second and even third shots, widening the gaps southward as planned. The work continued under enemy artillery fire that increased after H-hour. Then the demolitionists worked northward, widening cleared areas and helping demolish a seawall. By 0930, the teams had freed UTAH Beach of all obstacles. The Navy teams went out on the flats with the second ebb tide and worked until nightfall on the flanks of the beaches. At noon, the Army teams prepared to assist the assault engineers in opening the exit roads. The NCDUs and Army assault teams had completed most of the work by the time the support teams arrived. Within an hour, the engineers began to place explosives for breaching the seawall.

Although the action on UTAH Beach was not as severe as on OMAHA, the engineers did have problems in trying to construct roads off the beach. Less than half of the engineer's road-building equipment reached shore on D-day. Only 5 of 12 expected LCTs landed safely, all on the second tide. Many engineer vehicles drowned out when they exited into deep water. Hauling out such vehicles under enemy artillery fire proved one of the more difficult engineer tasks on D-day.

Artillery accounted for most of the personnel casualties in the 1st Engineer Brigade. The unit lost 21 who were killed and 96 were wounded on D-day. Strafing by enemy planes during the first evening caused most of the rest of the casualties.

While the assault teams blew obstacles, Companies A and C, 237th ECB, which had landed with the 8th Infantry at H-hour, created gaps in the seawall some 50 feet above high

water, removed wire, and cleared paths through the dunes to provide vehicle exits from the beach. Beyond the wall, a ridge of sand dunes, 10 to 15 feet high and 100 to 150 feet deep containing a 50-foot belt of mines, provided another obstacle to the engineers. Later in the morning, bulldozers arrived to build roads across the dunes.

Exit T-5, just north of Tare Green Beach, was flooded but had a hard surface and was usable during the first night. Exit U-5 at Uncle Red, above water for its entire length, became the first route inland leading to the village of Ste. Marie-du-Mont. South of U-5, near Pouppeville and the Douve River, lay the third road used on D-day, Exit V-1. Although in poor condition, the road was almost completely dry.

At the entrance to Exit U-5, the Germans had emplaced two Belgian Gates. Company A, 237th, blew them and also picked up several prisoners from pillboxes along the seawall. The engineers accompanied the 3d Battalion, 8th Infantry, inland along Exit U-5. About halfway across the U-5 causeway, they found that the Germans had blown a concrete culvert over a small stream. While the infantry proceeded, Captain Robert P. Tabb brought up a bridge truck and a platoon of Company B and began constructing a 30-foot treadway bridge, the first bridge built in the UTAH landing area. They were helped by men of the 238th ECB, who had landed around 1000 hours with the main body of the 1106th Engineer Combat Group.

Two companies of the 49th ECB accompanied the 2d Battalion, 8th Infantry, on its march south to Pouppeville. The engineers worked on Exit V-1 from the beach through Pouppeville to the north–south inland road, while the infantry made contact with the 101st Airborne Division. Company G, 8th Infantry, had the mission of capturing the locks southeast of Pouppeville that the Germans had manipulated to flood the pastureland behind Tare Green and Uncle Red beaches. An enemy strongpoint farther south at Le Grand Vey protected the locks.

While the infantry passed the locks, the 49th's Company A secured them, took 28 prisoners, and dug in defensively to protect them from recapture. The next day, the company overcame the German strongpoint at Le Grand Vey, capturing

59 prisoners, 17 tons of ammunition, large numbers of small arms, and three artillery pieces.

By dark on D-day, the 1st ESB had opened Sugar Red. It had cleared the beach of mines and wrecked vehicles; improved the roads; set up route markers; and made Exit T-5, the road leading inland from Sugar Red, passable for vehicles. It also established dumps for ammunition and medical supplies and found sites for other dumps behind the beaches.

During the period of organizing the beach, several members of the 1st ESB distinguished themselves in action. First Lieutenant Sidney Berger received the Silver Star for saving the lives of several men during an artillery attack. Private Everett Brumley received the Silver Star for rescuing a blinded, wounded soldier staggering along the beach. Sergeant James C. McGrath was awarded the Bronze Star for sweeping for mines while under artillery fire and rendering first aid to one of his men who was seriously wounded by a mine.

Although the troops generally ran behind schedule on OMAHA, at UTAH the entire 4th Division, with 20,000 men and 1,700 vehicles, was ashore within 15 hours after H-hour. The major difference between the two beaches was the absence of Teller mines on the obstacles at UTAH. The lack of mines enabled dozer work on UTAH to proceed faster. Even so, enemy fire took 10 percent of NCDU personnel and more than 8 percent of Army personnel.

Despite the doubts and fears of the early hours on OMAHA, the invasion was successful. That success was, in great part, attributable to the efforts of the engineers. They contributed to the victory in their dual role as engineers and infantry. Without their effort in destroying obstacles on the beach, clearing minefields, constructing exit roads off the beach, and fighting in the line as infantrymen, the invading force might not have held the beachhead and established the critical toehold in Nazi-occupied Europe.

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Engineers in the Battle of the Bulge

by William C. Baldwin

Although D-day gave the western Allies a beachhead in northern France, it took them almost two months of bitter fighting to break out of the Normandy hedgerows. After the breakout, Allied armies raced across France, liberated Paris, and headed toward the German frontier. The rapid pace of the advance placed a severe strain on Allied logistics, which, along with bad weather and stiffening German resistance, slowed the offensive. By mid-December, American armies had reached the Roer River inside Germany and the West Wall along the Saar River in eastern France. Between these two fronts lay the Ardennes, a hilly, densely forested area of Belgium. The Germans had attacked France through this supposedly impassable region in 1940.

In early December 1944, five American divisions and a cavalry group held the 85-mile-long Ardennes front. The difficult terrain of the region and the belief that the German army was near exhaustion had convinced the Allied commanders that the Ardennes sector was relatively safe. Thus, three of the divisions were new, full of green soldiers who had only recently arrived on the continent; the other two were recuperating from heavy losses suffered in the bitter fighting in the Huertgen forest farther north. In addition, the heavy demand for American troops in some sectors had forced Allied commanders to lightly man other portions of the front.

After months of retreat, Hitler decided on a bold gamble to regain the initiative in the west. Under the cover of winter weather, Hitler and his generals massed some 25 divisions opposite the Ardennes and planned to crash through the thinly held American front, cross the Meuse River, and drive to Antwerp. If the offensive succeeded, it would split the British and American armies and, Hitler hoped, force the British out of the war. Before daybreak on 16 December 1944, the German army launched its last desperate offensive, completely surprising the American divisions in the Ardennes.

One of the new divisions there was the 106th Infantry, which had relieved the 2d Infantry Division starting on 10 December. Its organic engineer combat battalion, the 81st, had begun road repair and snow removal in the division's sector. Behind the 81st was the 168th Engineer Combat Battalion (ECB), a corps unit, which had been operating sawmills and quarries. The massive German assault on 16 December quickly interrupted these routine tasks. Both battalions found themselves fighting as infantry in a brave but ultimately futile attempt to stem the German offensive.

The Ardennes

On the morning of 17 December, as German troops were cutting off and surrounding the regiments of the 106th, the division commander ordered Lieutenant Colonel Thomas J. Riggs, Jr., the commander of the 81st, to establish defensive positions east of the important crossroads at St. Vith. Reinforced by some tanks from the 7th Armored Division, elements of the two engineer battalions under Colonel Riggs held their position against determined German attacks until 21 December. During that afternoon, a heavy German assault, led by tanks and accompanied by intense artillery, rocket, and mortar fire, overran the exhausted American defenders. Colonel Riggs ordered his men to break up in small groups and attempt to escape to the rear. The Germans captured most of the survivors, including Colonel Riggs. For its participation in this action, the 81st Engineer Combat Battalion received the Distinguished Unit Citation, which praised its "extraordinary heroism, gallantry, determination, and esprit de corps."

The capture of Colonel Riggs began an odyssey which eventually ended with his return to his battalion several months later. The Germans marched their prisoners over 100 miles on foot to a railhead. During that march, Colonel Riggs lost 40 pounds. From the railhead, Riggs went to a prisoner of war camp northwest of Warsaw. He escaped from the camp and headed for the Russian lines, surviving on snow and sugar beets. Late one night, the Polish underground discovered him, and he joined a Russian tank unit when it captured the Polish village where the underground had taken him. After some time with the unit, Colonel Riggs joined a number of former Allied prisoners of war on a train to Odessa. From there, he went by ship to Istanbul and Port Said in Egypt, where he reported to American authorities. Riggs was eligible for medical leave in the States, but he insisted on rejoining his old unit, now in western France. On his way back to the unit, Riggs stopped in Paris for a debriefing and made his first contact with his unit when he ran into some engineers from the 81st in a bar. It was their first news of him since St. Vith.

Other divisional and nondivisional engineer units found themselves in situations similar to the 81st during the first few days of the German offensive. As the American front in

the Ardennes collapsed, General Dwight D. Eisenhower and his subordinates redeployed their forces as quickly as they could to meet the German attack; but while these troops were moving into position, the American commanders had to rely on rear area troops already in the Ardennes. Many of these were corps and army engineer battalions, scattered throughout the area in company, platoon, and even squad-sized groups. These small groups of engineers played important roles in the Battle of the Bulge.

Engineers sweep for mines in the snow during the Ardennes campaign.

Snaking their way along the twisted Ardennes road network, the German battle groups were bent on reaching the Meuse River with the least possible delay. As they advanced, U.S. Army engineers who had been engaged in road maintenance and sawmilling suddenly found themselves manning roadblocks, mining bridges, and preparing defensive positions in an effort to stop the powerful German armored columns. A few examples will show how these engineers imposed critical delays on an offensive whose only hope for success lay in crossing the Meuse quickly.

Lieutenant Colonel Joachim Peiper, a Nazi SS officer, led one of the armored columns racing toward the Meuse. His route took him near the town of Malmedy and toward the villages of Stavelot, Trois Ponts, and Huy on the Meuse. Trois Ponts was the headquarters of the 1111th Engineer

Combat Group, and one of its units, the 291st Engineer Combat Battalion, had detachments working throughout the area. When he learned on 17 December of the German breakthrough, the commander of the 1111th Group sent Lieutenant Colonel David E. Pergrin, the 27-year-old commander of the 291st, to Malmedy to organize its defense.

Although most of the American troops in the area were fleeing toward the rear, Colonel Pergrin decided to hold his position in spite of the panic and confusion. He ordered his engineers to set up roadblocks and defensive positions around the town. During the afternoon of the 17th, engineers manning a roadblock on the outskirts of Malmedy heard small arms fire coming from a crossroads just southeast of their position. Shortly thereafter, four terrified American soldiers staggered up to the roadblock. They brought the first news of the Malmedy massacre in which Peiper's troops murdered at least 86 captured American soldiers.

Peiper did not attack Malmedy, but headed instead toward Stavelot where Colonel Pergrin had sent another detachment of the 291st. Equipped with some mines and a bazooka, the detachment delayed the column for a few hours. A company of armored infantry eventually reinforced the engineer roadblock, but this small American force was no match for the German panzers. Peiper's column pushed through the village, and its lead tanks turned westward toward Trois Ponts.

Shortly before the Germans broke though the roadblock at Stavelot, Captain Sam Scheuber's Company C of the 51st Engineer Combat Battalion had taken up position in Trois Ponts. The 51st, also part of the 1111th Combat Group, had received orders to defend the village and prepare its bridges for demolition. While another detachment of the 291st wired one bridge south of the village, Company C, reinforced by an antitank gun and a squad of armored infantry, prepared its defenses. When Peiper's tanks came into view, the engineers blew up the main bridge leading into the village. Although the river separating Trois Ponts from the German column was shallow enough for infantry to ford, it was an effective barrier to tanks. A detachment of German tanks headed down the river looking for another bridge, while other tanks and infantry remained behind, across the river from the village.

By the evening of 18 December, the small American force at Trois Ponts had come under the command of Major Robert B. Yates, executive officer of the 51st Combat Battalion, who had come to the village expecting to attend a daily staff meeting. Fearing that the Germans would discover the weakness of his force, Major Yates tried to deceive the enemy. During the night, the six trucks of the engineer company repeatedly drove into Trois Ponts with their lights on and drove out with the lights off, simulating the arrival of reinforcements. The engineers put chains on their single 4-ton truck and drove it back and forth through the village to create the impression that there were tanks in Trois Ponts. An American tank destroyer, which had slipped off the road and into the river a few days earlier, provided the artillery. It caught fire and its 105-mm. shells exploded at irregular intervals throughout the night. The ruses apparently worked, because the Germans never launched a determined attack on the village.

On 20 December, the 505th Parachute Infantry Regiment of the 82d Airborne Division, which was trying to block the German penetrations, learned of the small force holding Trois Ponts. When the regiment moved into the village during that afternoon, Major Yates greeted its commander with, "Say, I'll bet you fellows are glad we're here!" American troops finally stopped and destroyed Peiper's armored column a few days later; they had received invaluable assistance from the engineers who had delayed the Germans and forced them into costly detours.

Farther south, engineers were also caught up in the massive German attack. On 17 December, the VIII Corps commander ordered his 44th Engineer Combat Battalion under Lieutenant Colonel Clarion J. Kjeldseth to drop its road maintenance, sawmilling, and quarrying operations and help defend the town of Wiltz in Luxembourg. The 600 men of the 44th joined a ragtag force consisting of some crippled tanks, assault guns, artillery, and divisional headquarters troops. Attacked by tanks and infantry on the 18th, the engineers held their fire as the tanks roared by and blasted the German infantry following behind. Forced to retreat by the weight of the German attack, the defenders moved back into the town and blew up the bridge over the Wiltz River. By the next

evening, the small American force was surrounded and running low on ammunition. The soldiers attempted to escape but few made it back safely. Among the heavy American casualties was the equivalent of three engineer companies dead or missing, but the defenders of Wiltz had slowed the German advance and given other American troops time to rush to the defense of the critically important crossroads some 10 miles to the west—the town of Bastogne.

With the American defenses collapsing west of Bastogne, the corps commander ordered the last of his reserves, the 35th Engineer Combat Battalion—a corps unit—and the 158th Engineer Combat Battalion—an army unit which happened to be working in the area—to defend Bastogne until reinforcements could arrive. On the morning of the 19th, German tanks attacked an engineer roadblock in the darkness. Unsure of his target in the gloom, Private Bernard Michin waited until a German tank was only 10 yards away before firing his bazooka. The explosion which knocked out the tank blinded him. As he rolled into a ditch, he heard machine gun fire close by. He threw a grenade at the sound, which ceased, and struggled back to his platoon. Private Michin, who regained his sight several hours later, received the Distinguished Service Cross for his bravery under fire. During the evening of the 19th and the morning of the 20th, the 101st Airborne Division, which had rushed to the defense of Bastogne, relieved the 158th and the 35th ECBs.

German panzers and troops continued to push west and north of Bastogne, eventually surrounding the American defenders in the town. These German penetrations threatened an American Bailey bridge over the Ourthe River at Ortheuville on the main supply route to Bastogne. Another combat battalion, the 299th, had prepared the bridge for demolition; and one of its platoons, reinforced by some tank destroyers on their way to Bastogne, was defending the bridge when German troops attacked early on 20 December. Alerted the previous evening to help defend the bridge, a platoon of the 158th arrived as German troops seized it. The platoon crossed the river and attacked the German flanks. By noon, the engineers and tank destroyers forced the enemy to withdraw. Reinforced by the rest of the 158th under Lieutenant Colonel Sam Tabet, the engineers held open the road to Bastogne

for a few hours and allowed supplies of fuel and ammunition to reach the town. By evening, German tanks closed the road again and attacked the bridge at Ortheuville. In spite of mines the 158th had hastily planted on the road in front of the bridge, the tanks seized it. When the engineers attempted to demolish it, the bridge failed to blow up. Having delayed the enemy advance for a day and allowed some more supplies to reach beleaguered Bastogne, the 158th retired to the west to establish still more barrier lines.

A soldier from the 51st Engineer Combat Battalion checks a TNT charge during the Battle of the Bulge.

Just a few miles to the southwest, engineers of the 35th Combat Battalion occupied positions blocking another crossing of the Ourthe River and, reinforced by an engineer base depot company, held off German tanks and infantry for most of the day. In the meantime, engineers to the rear blocked roads using minefields, abatis, blown culverts, and felled trees. When the Germans brought artillery to bear on the positions of the 35th, it retired under the cover of darkness, but only after imposing yet another delay on the German advance.

The German panzer columns that broke through the engineer defenses on the upper reaches of the Ourthe River drove north and west farther into the American rear area.

The 51st Engineer Combat Battalion defended this bridge over the Ourthe River, Hotton, Belgium.

At Hotton they encountered another Ourthe River bridge, a class 70 timber span, defended by engineers from the 51st Combat Battalion. After Company C had been ordered to Trois Ponts, the rest of the battalion under the command of Lieutenant Colonel Harvey Fraser established barrier lines in the area of Rochefort, Marche, Hotton, and from there a few miles farther north. For the first few days, the engineers' major problems were caused by the flow of American stragglers streaming to the rear and groups of German soldiers disguised as Americans. On the 20th, however, the forward positions of the 51st along the Ourthe toward La Roche came under German attack, and by early morning on the next day, enemy armor reached Hotton.

A makeshift force of engineers and others under the commander of Company B, Captain Preston Hodges, held the Hotton bridge. In addition to two squads of engineers, Hodges' small force included a 7th Armored Division tank, which the engineers discovered in a nearby ordnance shop. They prevailed upon the crew to join in their defense of the bridge. More reluctant was the crew of a .37-mm. antitank gun, but Private Lee Ishmael of the 51st volunteered to man the weapon.

At 0700, the Germans began shelling Hotton, and German tanks pushed past a small 3d Armored Division force on the far side of the river. As a Tiger tank approached the bridge, Private Ishmael engaged it with his .37-mm. gun and Sergeant Kenneth Kelly attacked it with a bazooka. One .37-mm. round wedged between the turret and the hull, and as the smoke cleared, the 51st saw the German crew abandoning the tank. When two more tanks approached the American positions, the 7th Armored tank knocked one of them out and the other slipped behind some buildings near the bridge. An unidentified soldier volunteered to flush out this tank and crossed the bridge with a bazooka and two rounds of ammunition. Minutes later, Captain Hodges heard an explosion that sounded like a bazooka round, and the German tank slipped into view between two buildings. The 7th Armored tank fired into the opening, destroying the panzer. The tank–infantry battle raged into the afternoon, but the engineers held the bridge until reinforcements arrived from the 84th Infantry Division, one of the many Allied units now rushing to block the German penetrations. The 51st Engineer Combat Battalion continued to man roadblocks and hold bridges in the area until 3 January.

Throughout the Ardennes, divisional, corps, and army engineer units on the front lines and in rear areas participated valiantly in a sometimes desperate attempt to stem the tide of the unexpected German counteroffensive. After the American front in the Ardennes collapsed under the weight of the massive attack, few American units, except engineers, were prepared to resist. Engineer officers, like Riggs, Pergrin, Fraser, and Yates, insisted on staying in their positions, even when other Americans fled to the rear. Relying on their training in defensive operations, engineer troops established roadblocks with whatever troops and weapons were at hand, blew up bridges, planted minefields, and succeeded, often at the cost of heavy casualties, in delaying the powerful German armored columns. The delays that engineers helped to impose gave the Americans and British time to bring in reinforcements and seal off the German penetrations.

The Battle of the Bulge demonstrated that engineer initiative and training in defensive operations could make a major contribution to the outcome of an important campaign.

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Janice Holt Giles' lively story of the 291st Engineer Combat Battalion's exploits, *The Damned Engineers*, was originally published in 1970 and reprinted by the Office of History, Office of the Chief of Engineers, in 1985.

The same office resurrected an account of another battalion's activities, written shortly after the events, from the files of the National Archives and published it in 1988 as *Holding the Line: The 51st Engineer Combat Battalion and the Battle of the Bulge, December 1944–January 1945*. The author was Ken Hechler, and Barry W. Fowle added a prologue and epilogue.

check on the serviceability of the bridge for infantry passage. An explosion occurred about two-thirds of the way over damaging some of the decking, but the men continued, searching out explosives. They found four charges in the middle of the bridge and cut the wires. Rifle fire cut the heavy wires leading into a master switchbox, and an engineer found an unexploded 500-pound charge in a tower with the fuse cap blown, probably the result of defective TNT. The team continued to examine the bridge, cutting wires where found.

As engineers arrived, they were put to work repairing the bridge and clearing mines on the east bank. By midnight, 7 March, the engineers had completed hasty repairs and traffic began to cross. Early on the 8th, engineers found and removed an additional 1,400 pounds of explosives from wells in the bridge piers. On 10 March, the 276th Engineer Combat Battalion (ECB) took over bridge maintenance.

Once the 9th Armored Division had captured and temporarily repaired the Ludendorff railway bridge, III Corps began planning for additional bridging service across the Rhine. The engineer plan, drawn up by Colonel F.R. Lyons, engineer, III Corps, called for three ferry crossings, one

The first tactical bridge across the Rhine built by the 291st Engineer Combat Battalion and two treadway companies spans the Rhine River between Remagen and Erpel, Germany. PFC Vernon H. Bradberry and PFC Clinton E. Farmer form a color guard, 19 March 1945.

treadway bridge, one reinforced heavy ponton bridge, and protective mine booms for the bridges. Corps gave Lieutenant Colonel Kenneth E. Fields, commander of the 1159th Engineer Combat Group (ECG), the command of the engineer units at Remagen.

The 86th Engineer Heavy Ponton Battalion, supported by a platoon from the 299th ECB, got the mission of constructing and operating three ferries across the Rhine. The first ferry, just downstream from the Ludendorff bridge, went into operation at 1100 hours on 9 March. The 86th built two additional ferries, one at Kripp upriver from Remagen and the other at Unkel just below the first ferry. It constructed all three under artillery fire, and at Kripp it encountered machine gun fire. The ferries moved vehicles across the Rhine until 13 March when an M-2 steel treadway and a reinforced heavy ponton bridge began to take most of the traffic. They operated until discontinued on 26 March.

Lieutenant Colonel David E. Pergrin's 291st ECB, supported by the 998th and 988th Engineer Treadway Bridge (ETB) Companies, got the mission of building a treadway bridge at Remagen just below the Ludendorff bridge. The battalion began work at 0830 hours on 10 March, constructing the bridge from the near shore to the far shore. Heavy artillery, sniper fire, and bombing caused 35 casualties during

The 51st Engineer Combat Battalion completed the second tactical bridge across the Rhine River at Kripp, Germany, 11 March 1945.

construction. Debris flowing against the bridge caused additional problems for the builders. The 291st completed the bridge at 1700 hours on 11 March. It was the first tactical bridge constructed across the Rhine by Allied troops.

Lieutenant Colonel Harvey R. Fraser's 51st ECB, supported by the 181st and 552d Engineer Heavy Ponton Battalions, constructed the second bridge across the Rhine. It was a reinforced heavy ponton bridge at Kripp. Bridge construction began at 1630 hours on 10 March. Initially, delays occurred because of difficulty in securing the far shore. Artillery fire and occasional bombing contributed to the problems. Major William F. Tompkins of the 552d was killed by an enemy bomb during construction. The 51st completed the bridge at 2200 hours on 11 March, and III Corps named it after Tompkins.

Once the battalions completed those two bridges, the 1159th closed the Ludendorff bridge, and Lieutenant Colonel Clayton A. Rust's 276th ECB got the job of repairing it. A technical team from the 1058th Port Construction and Repair Group assisted.

The east end of the collapsed Ludendorff railroad bridge, which spilled several hundred engineers into the Rhine River, 17 March 1945.

On the day the Ludendorff bridge collapsed, ten days after its capture, the 148th ECB began building a class 40 floating Bailey bridge at Remagen, downstream from the Ludendorff. A company of the 291st ECB assisted. The 148th started the bridge at 0730 hours on the 18th and completed it in 48 hours.

The 164th ECB constructed the protective river booms for the bridges at Remagen. It used three types of booms: an impact boom, a mine net, and a log boom. Considerable debris collected on the net boom requiring constant maintenance.

On 12 March, with the III Corps bridgehead at Remagen firmly established, First Army decided to cross VII Corps on the left of III Corps. The 78th Infantry Division, already across in the III Corps bridgehead, drove north to seize the line of the Sieg River below Bonn. The 1st Division passed through the 78th and secured its east flank. One combat command of the 3d Armored Division supported the two divisions. Colonel Mason J. Young, engineer, VII Corps, planned and supervised the construction of bridges across the Rhine in the corps zone. As the infantry cleared areas of enemy small arms and machine gun fire, engineers built bridges at desirable sites. Equipage for the construction of two M-2 steel treadway bridges and one reinforced heavy ponton bridge was available. Concurrently with the construction of each bridge, a ferry was also put into operation. The first ferry, at Rolandseck, was a standard five-ponton ferry; but the next two, at Konigswinter and at Bonn, were reinforced six-ponton ferries designed to take the M26 tank. Ferry traffic was light with loads consisting mainly of heavy tanks.

The first bridge site uncovered was at Rolandseck, at the location of an existing civilian ferry. Lieutenant Colonel John G. Shermerhorn, 1120th ECG, commanded the troops constructing two bridges. Lieutenant Colonel Julian P. Fox's 297th ECB constructed a treadway bridge on 16 March, completing the job in less than 37 hours.

The 294th ECB, under Lieutenant Colonel Charles A. Grennan, supported by the 86th, 181st, and 552d Engineer Heavy Ponton Battalions, began construction on the reinforced heavy ponton bridge at 2210 hours on 18 March. It was opened to traffic the next afternoon.

Colonel Robert Erlenkotter, 1106th ECG, commanded the troops building the last tactical bridge in the VII Corps area. The 237th ECB started the M-2 steel treadway bridge at 0615 hours on 21 March at the site of an existing ferry in Bonn. It completed the 1,308-foot bridge, the longest of the tactical bridges built across the Rhine at that time, in less than 12 hours. The excellent time was a direct result of experience from earlier bridges built.

Once VII Corps crossed the Rhine, V Corps was ordered to cross in the bridgehead area south of III Corps. There was equipage available for the construction of one M-2 steel treadway bridge. Colonel Lewis C. Patillo, engineer, V Corps, planned and supervised the crossing by V Corps engineers. Colonel Robert K. McDonough, commanding officer, 1121st ECG, was commander of troops; and Lieutenant Colonel Loren A. Jenkins' 254th ECB constructed the 1,368-foot bridge at Honningen with assistance from the 994th and 998th Engineer Treadway Bridge (ETB) Companies. The 164th constructed protective booms upstream from the bridge. Engineers started the bridge on 22 March from both banks and completed it 12 hours later. It was the longest in the First Army area.

Shortly after the capture of the Ludendorff railroad bridge, First Army decided to construct a two-way Bailey bridge on barges at Bad Godesberg, about 5 miles south of Bonn. On 12 March, Colonel John T. O'Neill, commander of the 1110th ECG, directed his engineers to find barges and prepare for construction. The 148th, 207th, and 1264th ECBs began work on 25 March; and on 6 April, the 1110th opened the bridge for traffic.

Engineers used two types of barges on the bridge: those with a 17-foot beam and 125 to 130 feet in length and those with a 17-foot beam and 220 to 270 feet in length. The capacity of the former was 250 tons, and of the latter, 1,500 to 2,000 tons. The builders used the large barges for landing bay piers and the smaller as floating piers.

Once the engineers completed all of the tactical bridges over the Rhine, and division and corps units moved forward, Army gave the 1110th ECG, supported by the 5th and 164th ECBs, the mission of maintaining and guarding the bridges.

Lieutenant General George S. Patton's Third Army was second across the Rhine. It initiated planning for crossings in the vicinity of Mainz in August 1944. Brigadier General John Conklin, the Army engineer, established a special staff section which formulated the engineer plan and estimated needed equipment and material. He set up schools to train engineer as well as Navy units in the use of landing craft on rivers. Toul, France, became the assembly point for stocks of needed bridging equipment. Third Army assembled a huge fleet of trucks to move equipment from the storage dumps at Toul, Esch, and Arlon to the Rhine, a 300-mile round trip, made longer than normal because of uncleared roads and a lack of bridges.

On 22 and 23 March, XII Corps crossed in the vicinity of Nierstein, where a good network of roads intersected and where hills and a town masked engineer approaches on the west bank. The 1135th Engineer Combat Group under Colonel Alfred Dodd Starbird (later lieutenant general) directed the operation, using 600 motorized storm boats and 300 motorized assault boats. Some 18 engineer units attached to the 1135th Group supported the crossing. It started at 2200 hours on 22 March with the 204th ECB paddling the 11th Infantry across in assault boats. By dawn, most of the 5th Infantry Division had crossed. The following evening, a bridge spanned the river; and within the next five days, engineers successfully executed three more crossings. At this point, all resistance along the Rhine on the Third Army front had collapsed.

The first bridge across the Rhine in the Third Army area was at Oppenheim. Begun by the 150th ECB at night on 22 March, the men inflated the floats in the rear and carried them forward on trucks. By daybreak, the engineers had assembled the floats into rafts and started work on the bridge at an old ferry site. By 1800 hours, the class 40, M-2 treadway bridge was taking traffic. The 87th Engineer Heavy Ponton Battalion began a second bridge on 23 March and completed the 1,280-foot class 24 bridge just after midnight. It was later reinforced to carry class 40 loads. To speed traffic at a faster rate, corps ordered another treadway bridge put in. The 150th started work on the 24th and opened the bridge at noon on 25 March.

By 27 March, five divisions—as well as supplies and necessary supporting troops—had passed over these three bridges. The entire 6th Armored Division crossed in less than 17 hours. During the period from 24 to 31 March, 60,000 vehicles crossed the bridges at Oppenheim.

At the same time the crossing of XII Corps was under way, army made plans to support a crossing of VIII Corps in the great gorge of the Rhine which runs from Bingen to Ober Lahnstein. Ancient castles dotted the steep cliffs along the river. Crossing in this area presented a problem. The approaches to the river valley on each side were over steep, winding roads cut into the sides of the gorge, exposing any vehicle movement to the enemy on the far shore. Once reached, the river presented a problem in that it ran 6 to 8 feet per second over a rocky bottom making anchorage of floats difficult.

The VIII Corps plan called for a crossing to be made by the 87th Infantry Division in paddled assault boats on 25 March, with one run in the vicinity of Rhens and another at Boppard, the main site. The initial assault wave crossed successfully at both areas. Strong enemy resistance was encountered at Rhens and this site was abandoned when the Boppard crossing proved less difficult. Engineers constructed infantry support rafts to carry light vehicles and M-2 treadway rafts to carry tanks. An M-2 treadway bridge was started by the 44th ECB at 0800 hours on the morning of the assault and completed in less than 26 hours.

While this operation was under way, VIII Corps started another crossing the night of 25–26 March at St. Goar and Oberwesel. As with the other crossings, paddled assault boats made the initial crossing with powered assault boats carrying the troops in the succeeding waves. Infantry cleared St. Goar by the morning of 27 March, and the 243d ECB started a treadway bridge. It completed the 828-foot, class 40 treadway bridge 36 hours later. Again, the swift current and a poor river bottom caused problems with anchorage.

The XX Corps decided on two assault crossings at Mainz in a difficult and strongly resisted operation. The initial waves of the 80th Infantry Division crossed secretly in boats paddled by the 135th ECB, while the succeeding waves crossed in double assault boats and storm boats powered with outboard

motors. From the time the first craft went into operation until the treadway bridge was open some 34 hours later, the Navy transported an estimated 7,000 troops and about 600 vehicles, a magnificent job considering the river was about 2,000 feet wide at Mainz.

The 1,896-foot treadway bridge was built under fire at Mainz, Germany, 23 March 1945.

The 160th ECB, commanded by Lieutenant Colonel J.H. Jackson, began construction of an M-2 treadway bridge at Mainz on 28 March. In spite of enemy artillery action and with the help of the 997th Engineer Treadway Bridge Company, it completed the bridge in 22 hours. The engineers used 154 pontons in completing the 1,896-foot bridge, the longest tactical bridge built in the European theater of operations. In addition to serving the 80th Infantry Division, it served the entire XX Corps in crossing the Rhine. It also ended the assault phase of the Rhine operations in the Third Army area.

Ninth Army began its first crossing just south of Wesel at 0200 hours on 24 March after one of the heaviest artillery barrages of the war. The 1153d Engineer Combat Group ferried most of the 30th Infantry Division across the Rhine in four hours, using assault and storm boats. By noon, the 1153d had two Bailey rafts and several treadway rafts in operation, moving tanks across the river.

The 160th Engineer Combat Battalion built the longest tactical bridge across the Rhine at Mainz, Germany, 23 March 1945.

The 79th Division, supported by the 1148th Engineer Combat Group, began its assault on the right about 0330 hours and crossed almost as quickly. By 0600 hours, one regiment of the 79th was across, and by 1345 hours, the 149th and 187th ECBs had ferried across the last regiment. Shortly after the initial crossings, landing vehicles, tracked (LVTs) and 2 1/2-ton amphibious trucks (DUKWs) began transporting ammunition and supplies. By early afternoon, 24 landing craft, vehicle and personnel (LCVPs) and 20 landing craft, medium (LCMs) were in operation transporting vehicles, armor, and artillery across.

Bridge construction began earlier than planned on 24 March because of the light enemy resistance encountered. In the 79th Division zone at Milchplatz, the 208th ECB, under the 1103d ECG, built a 1,260-foot M-2 treadway bridge. Three runaway LCMs and enemy artillery fire delayed completion until 1800 hours on 26 March. In the 30th Division area, corps units built three additional bridges before army engineers took over bridging operations. Construction of a 1,110-foot M-1 treadway bridge was begun at 0630 hours on 24 March and opened to traffic 26 hours later. A 1,152-foot, 25-ton ponton bridge at Wallach, begun at 0600 on 24 March, opened to traffic at 0630 hours the next morning. Work on the last of the three bridges in the 30th Division area

Overnight the engineers built this ponton bridge spanning the Rhine River in the vicinity of Wallach, Germany, 25 March 1945.

began at 0630 hours on 24 March. This M-2 treadway opened for traffic at 1600 hours the same day, but a Bailey raft loaded with an M4 tank knocked it out of service until just after midnight.

Army engineer units rapidly relieved corps engineers of all responsibility for bridging the Rhine and began three floating Bailey bridges, a 25-ton ponton bridge, a treadway bridge, a class 70 ferry, and the necessary booms for bridge protection. The 172d ECB, supported by one company of the 278th ECB, began construction of a class 40 Bailey bridge on 26 March at Mehrum. At Wallach, the 1143d ECG, with its 277th, 336th, and 244th ECBs, got the mission of constructing a class 40 Bailey bridge and three protective booms. The 277th ECB built the 1,739-foot bridge in three days, opening it to traffic on 29 March.

Army assigned the 1117th ECG the missions of constructing a class 40 M-2 floating treadway, a class 36, 25-ton ponton, and a class 40 Bailey bridge at Wesel. In addition, the battalion had to construct and operate a class 70 ponton ferry, and install six booms. The 1253d ECB built and maintained the access roads to the bridge sites, and the 248th ECB constructed the M-2 treadway bridge and class 70 ponton ferry. Engineers began work on the 1,284-foot treadway at 1505 hours on 25 March and completed it in 13 hours.

The Ninth Army at Wesel cross the Rhine on a ponton bridge built by the 167th Engineer Combat Battalion, 1117th Engineer Combat Group.

The 551st Heavy Ponton Battalion, with Companies B and C of the 1253d ECB, constructed a 25-ton ponton bridge. They started the bridge at 2000 hours on 25 March and completed it in less than 23 hours. The 167th ECB built the third Bailey bridge. Construction of the 1,415-foot bridge began at 0600 hours on 26 March and opened to traffic at 1900 hours the next day.

The 1146th ECG got the mission of constructing a two-way class 40, one-way class 70, pile trestle, fixed bridge over the Rhine and Lippe rivers at Wesel. The 250th and 252d ECBs, supported by the 1053d and 1058th Port Construction and Repair Groups, built the Rhine River portion of the bridge. The 1256th ECB constructed the Lippe River bridge. The 1,700-foot bridge was finished after 21 days on 18 April.

In the Seventh Army area, D-day was 26 March with the first crossing of the Rhine scheduled for 0230 hours. On the right or south, the 3d Infantry Division made the main assault crossing in the Bobenheim area after a heavy artillery preparation. To the north, the 45th Division crossed in the Hamm–Rhein Durkheim area without an artillery preparation. Engineers encountered some resistance in the initial wave, but more in subsequent waves, resulting in the loss of nearly half the assault craft.

Engineers in both assault zones began construction of floating bridges as soon as small arms fire ceased to harass the men at the sites. The 540th Engineer Combat Group supported the 3d Infantry Division by constructing and operating two heavy ponton rafts and two infantry support rafts. By the end of the first day, the group had completed a 948-foot treadway bridge and a 1,040-foot heavy ponton bridge, the latter in just over nine hours.

In the 45th Infantry Division area, the 40th Engineer Combat Group operated two heavy ponton rafts and two infantry support rafts. Engineers started a heavy ponton bridge and a floating treadway bridge on 26 March and completed them the next day.

By 31 March 1945, all four American armies had crossed the Rhine River. The last great natural barrier protecting the German heartland had fallen. As in all other ground operations in Europe, engineers played a critical role in the planning and successful execution of the assault crossings. In 40 days, Germany would surrender, and the war in Europe would end.

Sources for Further Reading

For a general overview of the Rhine River crossings, read the representative chapters in *United States Army in World War II, The Last Offensive* (Washington, DC: Office of the Chief of Military History, 1973).

Ken Hechler's *The Bridge at Remagen* (New York: Ballantine Books, 1957) gives a good description of the action leading up to Remagen and the crossing of the Rhine.

For specifics on engineers bridging the Rhine, see: *The Rhine Crossing: Twelfth Army Group Engineer Operations* by General P.H. Timothy; *Report of the Rhine River Crossings: First United States Army* (Office of the Engineer, First United States Army, May, 1945); *Crossing of the Rhine River by Third U.S. Army* (Office of the Engineer); *Engineer Operations in the Rhine Crossing; Ninth U.S. Army* (Ninth U.S. Army, June 30, 1945); and *Report of Operations: The Seventh United States Army in France and Germany 1944–45*, 3 volumes (Heidelberg Gutenberg Printing Company, Heidelberg, Germany, May 1946).

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Acronyms and Abbreviations

AEB	Armored Engineer Battalion
AEF	Allied Expeditionary Force
AGC	Associated General Contractors of America
ALCAN	Alaska–Canada
ALCOA	Aluminum Company of America
AOG	American Oil and Gas Corporation
ASF	Army Service Forces
ASFTC	Army Service Forces Training Center
AUS	Army of the United States
BERH	Board of Engineers for Rivers and Harbors
BOB	Bureau of the Budget
BPA	Bonneville Power Administration
CAA	Civil Aeronautics Administration
CANOL	Canadian Oil
CBI	China–Burma–India
CBR	California Bearing Ratio
CE	Corps of Engineers
CQM	Constructing Quartermasters
CRREL	Cold Regions Research and Engineering Laboratory
DPC	Defense Plant Corporation
DSC	Distinguished Service Cross
DUKW	2½-ton 6×6 Amphibious Truck
EAB	Engineer Amphibian Brigade
EAC	Engineer Amphibian Command
ECB	Engineer Combat Battalion
ECG	Engineer Combat Group
ED	Editor, Edition
ERTC	Engineer Replacement Training Center
ESB	Engineer Special Brigade

ET	Engineer Training
ETB	Engineer Treadway Bridge
FDR	Franklin D. Roosevelt
GIWW	Gulf Intracoastal Waterway
GPO	Government Printing Office
HED	Honolulu Engineer District
IWC	Inland Waterways Corporation
JCS	Joint Chiefs of Staff
JNW	Joint Committee on New Weapons and Equipment
KLM	Royal Dutch Airlines (*Koninklijke Luchtvaart Maatschappij*)
LCI	Landing Craft, Infantry
LCM	Landing Craft, Medium/Mechanized
LCT	Landing Craft, Tank
LCVP	Landing Craft, Vehicle and Personnel
LSD	Landing Ship, Dock
LST	Landing Ship, Tank
LTC	Lieutenant Colonel
LVT	Landing Vehicle, Tracked
MBM	Mississippi Basin Model
MED	Manhattan Engineer District
MRC	Mississippi River Commission
MR&T	Mississippi River and Tributaries
MTP	Mobilization Training Program
MVA	Missouri Valley Authority
NATO	North Atlantic Treaty Organization
NCDU	Naval Combat Demolition Unit
ND	No Date
NCO	Noncommissioned Officer
NO	Number
NP	Not Published

O	OMAHA
OCE	Office of the Chief of Engineers
OCS	Officer Candidate School
ODT	Office of Defense Transportation
PAP	Pierced Aluminum Plank
PBS	Prefabricated Bituminous Surfacing
PC&R	Port Construction and Repair
POA	Pacific Ocean Area
POL	Petroleum, Oil, and Lubricants
POW	Prisoner of War
PRA	Public Roads Administration
PSP	Pierced Steel Plank
RADAR	Radio Detecting and Ranging
RCT	Regimental Combat Team
RET	Retired
SHAEF	Supreme Headquarters, Allied Expeditionary Force
SOS	Services of Supply
SS	Steamship
SWPA	Southwest Pacific Area
TRADOC	Training and Doctrine Command
TVA	Tennessee Valley Authority
U	UTAH
UCRB	Unit Construction Railroad Bridge
US	United States
USA	United States Army
USO	United Service Organizations
VOL	Volume
WES	Waterways Experiment Station
WPA	Works Progress Administration
WRC	Water Resources Committee

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